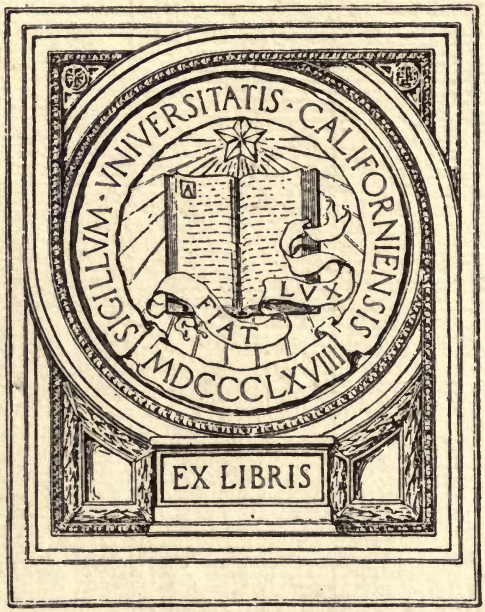

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THE WONDER OF LIFE

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THE WONDER OF LIFE

By

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PREFACE

THE aim of this book is to illustrate the ever-growing wonder of animated Nature—with especial reference to animal life. It is an unconventional introduction to Natural History and Biology, taking broad views of the actual lives of living creatures and working inwards. It is therefore complementary to other books which begin with the minute analysis of the individual. The author hopes that it may be found useful in 'Nature-Study' as a continuation of his *Biology of the Seasons*, and that teachers of Zoology may recommend it to their students as an introduction to the study of some of the problems for the discussion of which our crowded curricula leave little time.

Recent years have brought us a great increase of knowledge in regard to the haunts of life, such as the Deep Sea; periodic movements such as the Migration of Birds; adaptations and inter-relations; animal behaviour, both instinctive and intelligent; the intricacy of life-histories and the drama of organic evolution. It has been possible, therefore, in this book to use many fresh facts and fresh lights to illustrate and illumine old problems. The result in the author's mind has been a strengthening of the conviction that the facts of life cannot, for biological purposes, be adequately re-described in mechanical formulæ. It is hoped, however, that dogmatism has been successfully avoided. *The Wonder of Life* must speak for itself.

Perhaps everything that lives would appear equally wonderful if we knew enough about it—'the leaf of grass no less than the journeywork of the stars . . . the pismire equally perfect—the egg of the wren—the tree-toad,

a *chef d'œuvre* for the highest—the narrowest hinge in my hand—and the mouse that is miracle enough to stagger sextillions of infidels.' The author of a recently-published admirable introduction to Zoology has used the motto—*Ἐν πᾶσι γὰρ τοῖς φυσικοῖς ἔνεστί τι θαυμαστόν*—and we could wish for no better, being equally persuaded of the cosmic magic. 'Prais'd be the fathomless universe, for life and joy, and for objects and knowledge curious.' It is indeed altogether wonderful, but to different minds different things appeal—to one the way of the eagle in the air, to another the meanest flower that blows. So we have taken a wide sweep in our survey.

It is also true that science and age are ever changing the focus of our wonder, for as Keats lamented, the rainbow has never been quite the same since Newton looked at it, and the sunbeam that used to steal through the shutters and dance to our half-awed delight many years ago is not quite such a wonder now. But new wonders have taken the place of the sunbeams of our childhood, and so it must always be for those who keep their eyes young, that is to say, scientific. If the half-wonders go, the wonder remains, and this—the fundamental mysteriousness of Nature—is what we meant our book—in performance so far short of our ambition—to illustrate.

My thanks are due to Miss Shinnie for her skilful illustrations, to the publishers for the considerate patience with which they have borne delays enforced by professional duties, and to Messrs. Macmillan for their kind permission to use Huxley's translation of Goethe's Aphorisms.

J. ARTHUR THOMSON.

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1914.

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CHAPTER I

THE DRAMA OF LIFE

(Vital Motives)

'She performs a play; we know not whether she sees it herself, and yet she acts for us, the lookers-on. . . .'

'Her mechanism has few springs—but they never wear out, are always active and manifold. . . .'

'The spectacle of Nature is always new, for she is always renewing the spectators. Life is her most exquisite invention; and death is her expert contrivance to get plenty of life.'

—*Goethe's Aphorisms*, translated by Huxley.

Succession of Players—Progress of the Drama—Primal Impulses—One Great Problem—Abundance of Individuals—Number of Species—Variety of Form—Variety of Bread-Winning—The Struggle for Existence—Thrust and Parry—Many Inventions—Intricate Situations—In Illustration: Cuckoo Spit—The Case of Horned Lizards—Love-Scenes—Family Life—Complications—Retrospect.

TO many observers of living creatures it has seemed as though they were being allowed to see just a little of a complex and long-drawn-out drama. All the world is the stage, on which, without any fall of curtain, scene has succeeded scene since life began. The stage is crowded, in spite of its spaciousness, and everywhere we see repetitions of the same episodes and situations on different scales. Here there is a scene among birds, and there the insects

show the same as if in miniature. What the mammals are acting is being caricatured by the amphibians; and so it appears all round, as if one were in a multiplying-mirror show. It is like a world of echoes.

Succession of Players.—The stage is crowded with actors and actresses who always appear to be artistic in their proper setting or scenery. Some are on the boards *as individuals* for minutes, like some of the microbes; some for hours, like some midges; some for days, like the adult and aerial phases of May-flies or Ephemerids; some for weeks, like the house-flies; some for months, like the humble-bees; some for years, like the eagle; some for centuries, like the Californian Big Trees; but all in turn yield to Time's tooth. So automatic, however, is the succession among the short-lived creatures which it is permitted to any one of us to observe, that no gap is ever apparent. There is always an understudy ready to fill the vacant place. When we lengthen out our vision scientifically we see, however, that in spite of the apparent sameness there is continual change, and that one cast succeeds another as age follows age. Many great actors of superlative merit, like the Sea-Scorpions, the Giant Saurians and the Flying Dragons, have altogether ceased to be, and have left no direct successors at all. Nor has their mantle fallen on any. The play goes on, but the players change.

Progress of the Drama.—The age-long drama, whose progress, or, it may be, merely changeful sequence, is called Evolution, was aptly likened by Samuel Butler to the development of a fugue, 'where, when the subject and counter-subject have been announced, there must thenceforth be nothing new, and yet all must be new. So through-

out organic nature—which is a fugue developed to great length from a very simple subject—everything is linked on to and grows out of that which comes next to it in order—errors and omissions excepted'. 'And yet all must be new', for it would not be a drama if it did not develop, and it would not be life if it were not creative. The Aristotelian maxim that there is nothing in the end which was not also in the beginning, is true if we believe that in the beginning was the Logos. Otherwise it requires safeguarding. For while individual development is the expression or realization of the given inheritance, it is a self-expression that can only come about by trafficking with the environment, and may greatly enrich itself in so doing. And similarly, through the ages, the evolving organisms have been trading with Time, and thus 'all must be new'.

Beyond doubt the most impressive fact about animate nature is the ascent of life. It has gone on, reaching from step to step in a manner for which we have no word but *progress*. Its historic movement, as Lotze finely said, is like that of an onward-advancing melody. It is a fact that nobler and finer forms of life have appeared on the world's stage as one geological period has succeeded another. The bodies of animals have become more complex and more controlled, that is to say in technical terms, more differentiated and more integrated. The life of the creature has escaped more and more from the thraldom of the environment. We instinctively think of a bird as the emblem of freedom. There has been an increasing amplitude in life, as is evident when we compare birds and mammals with amphibians and fishes, or insects and spiders with sea-urchins and medusæ. There has been, it appears to us, an increasing liberation of the Psyche;

there is more and more *behaviour* as we ascend, and we may even discern the springs of *conduct*.

It must not be supposed, however, that the history discloses any straightforward progress, for it is full of retrogressions and of strange culs-de-sac. The tapeworm

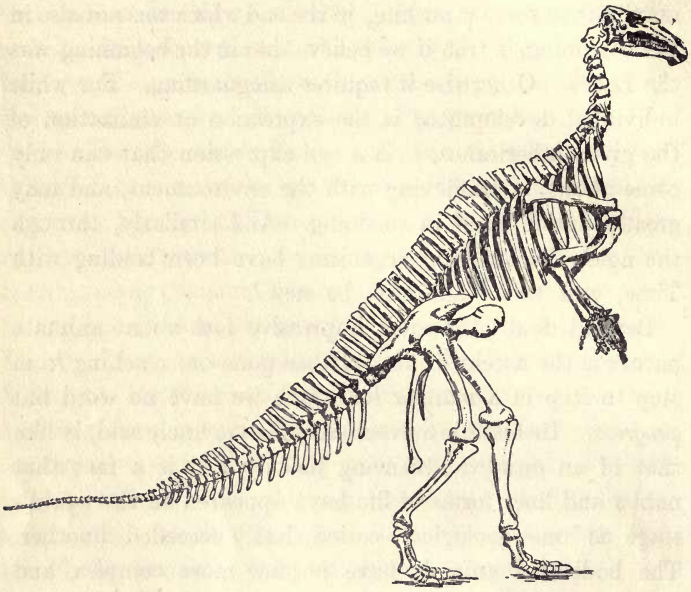


FIG. 2.—Extinct bipedal Reptile, *Iguanodon mantelli*, about 12 feet high. The genus is restricted to the Wealden (Cretaceous). (*After* Dollo.)

is as much a product of evolution as the bird, and is as well adapted to its inglorious lot as the lark to heaven's gate. There have been extraordinary failures, too, in the sense that many extinct types of great perfection have left no direct descendants. We do not know that their

particular excellences have in any way passed into those who continue the march, except in the very indirect sense, perhaps, that Man, for instance, is the stronger because of his early antagonists like the Cave Lion and the Cave Bear, who have long since ceased to be.

In the history of life we may recognize, with Bergson, three main lines of evolution. (I) There is the vegetative line, followed by plants, and in great measure by such animals as hydroids and corals. (II) There is the instinctive line, followed especially by the chitin-clad small-brained Arthropods (Crustaceans, Insects, Spiders, and the like). (III) There is the intelligent line, followed more especially by the Vertebrates, where an internal skeleton of bone usually takes the place of the Arthropod's external skeleton of chitin, and where the cerebral part of the nervous system attains high development. A Californian Big Tree, two thousand years old, may represent the climax of I; an ant the climax of II; and a man the climax of III.

Primal Impulses.—What in this world-fugue is the subject and what the counter-subject? There can be little doubt that the answer must be—Hunger and Love. These are the two primal impulses.

Warum strebt sich das Volk so, und schreiet?
Es will sich nähren, Kinder zeugen, und sie ernähren so gut es vermag.

These words 'hunger' and 'love' must not indeed be used woodenly; they correspond to self-preservation and race-continuance, to self-regarding and other-regarding, to nutrition and reproduction, to self-increase and self-multiplication, to feeding and flowering, and so on. It is

well understood that while Charles Darwin's grandfather wrote a book about *The Loves of the Plants*, it is not particularly useful for us to employ such a phrase. Nevertheless, it is entirely sound science to emphasize the fact that rich as plants are in adaptations which secure food, they are not less rich in adaptations which secure the nurture and dispersal and development of their offspring.

One is tempted sometimes to say that *the* primal impulse of organisms—even before hunger and love—is self-assertion, self-expression, and insurgence. But these big words are all covered by the little word 'life'. For life is activity, effective activity, regulated activity, self-assertive activity. If we start with this postulate, we may then say that the mainsprings of an organism's activity may be summed up in the words—'hunger' and 'love', the imperious motive forces of life.

One Great Problem.—As we contemplate the drama, both as we can see it with our eyes, and as we can see it with the help of telephotic apparatus (such as a palæontological museum!), we may discern that, in spite of all the variety, there is one perennial problem and endeavour, namely, to adjust relations between the active, self-assertive, insistent, insurgent organism and the inert, indifferent, heavy-handed environment. Living has often been described as action and reaction between the organism and the environment, but this is not quite adequate. The facts of the case have been better stated by Prof. Patrick Geddes. On the one hand, the Enviroment acts upon the organism, burning it and stoking it, heating it and cooling it, quickening it and slowing it, moistening it and drying it, exciting it and quieting it, and so on. The organism being acted

upon, the relation may be formulated as E→f → o (the first letters of the words Environment, function, and organism). On the other hand, the Organism (to which we may now give the capital letter) not only reacts, it acts. It hits back; it thrusts; it operates upon its environment. The environment being acted upon, the relation may be formulated as O→f→e. The real business of life is an adjustment of the twofold relation: $\frac{O \rightarrow f \rightarrow e}{E \rightarrow f \rightarrow o}$; and that is what we see continually going on in the drama of life.

Abundance of Individuals.—We have spoken of the crowded stage, and the prodigality of life is certainly one of its characteristics. Antarctic explorers have told us that in one haul of the dredge in those icy waters it was quite a usual thing to get from ten thousand to thirty thousand specimens of a certain Crustacean. On the surface of the small pools of water on the melting ice of the *mer de glace* at Chamonix, M. Vallot found in 1912 an extraordinary multitude of a rather rare wingless insect, the 'glacier flea', *Desoria nivalis*. These minute and primitive forms occurred over a stretch of glacier twenty metres broad by two thousand metres long, and there must have been forty millions of them!

The heather on the moor, with its firm leaves and apparently clean twigs, does not suggest itself as a crowded home of life, but that is just what it is, as Dr. Shipley found in searching for grouse-parasites. He adopted the method of soaking the heather in water and then centrifuging the infusion, with the result that an extraordinary wealth of little creatures was discovered. He gives a striking picture of what would appear if we could see a square yard of

the moor through a gigantic lens, magnifying a hundred times :—

'The heather plants would be as tall as lofty elms, their flowers as big as cabbages, the grouse would be six or seven times the size of 'Chantecler' at the Porte St. Martin ; creeping and wriggling up the stem and over the leaves, and gradually yet surely making their way towards the flowers, would be seen hundreds and thousands of silvery white worms about the size of young earthworms. Lying on the leaves and on the plant generally would be seen thousands of spherical bodies the size of grains of wheat, the cysts of coccidium [a minutely microscopic Protozoon parasite] ; and on the ground and on the plants, as large as split peas, would be seen the tapeworm eggs patiently awaiting the advent of their second host. It is perhaps a picture that will not appeal to all, yet it represents what, unseen and unsuspected, is always going on upon a grouse moor.' [*The Grouse in Health and Disease*, 1911.]

It may be said that the naturalist has beyond all others a discipline in the fine art that Blake spoke of as grasping infinity in the palm of the hand. Even about the dry twigs of the heather, there is a bustle of life.

Sometimes we get an impression of the prodigal wealth of life with overwhelming convincingness. Describing a visit to a Lapland bird-berg, the nesting-place of guillemots, razor-bills, and puffins, the naturalist Brehm wrote :—

'The whole hill was alive. Hundreds of thousands of eyes looked upon us as we intruded. From every hole and corner, from every peak and ledge, out of every cleft, burrow, or opening, they hurried forth, right, left, above, beneath ; the air, like the ground, teemed with birds. From the sides and from the summit of the berg thousands

threw themselves like a continuous cataract into the sea in a throng so dense that they seemed to the eye to form an almost solid mass. Thousands came, thousands went, hundreds of thousands swam and dived, and yet other hundreds of thousands awaited the footsteps which should rouse them also. There was such a swarming, whirring, rustling, fluttering, flying, and creeping all about us that we almost lost our senses. . . . The cloud of birds around us at the summit was so thick that we only saw the sea dimly and indefinitely as in twilight. . . . The millions of which I had been told were really there.'

Speaking of the dense swarms of haddocks and the like which throng at the spawning time into the Norwegian fjords, the same naturalist says :—

'Animated, almost maddened, by one impulse, the fish swim so thickly that the boat has literally to force a way among them, that the overweighted net baffles the combined strength of the fishermen or breaks under its catch, that an oar placed upright among the densely packed crowd of swimmers remains for a few moments in its position before falling to one side.'

Perhaps this final touch is exaggerated, but the general impression has been verified many times in the lochs in the West of Scotland.

The prodigal abundance of larger forms of life implies the still greater abundance of small fry, for all are linked by nutritive chains. It is in the open-water of lake and sea that we get our best impressions of multitudinousness. At the spring maximum of the Rotifer or Wheel-Animalcule called *Synchœta*, there may be about three millions to a square yard of lake ; at the summer maximum of the slimy

Alga, *Clathrocystis æruginosa*, there may be 500 millions to the square yard; at the autumn maximum of a well-known Diatom *Melosira varians*, which has a summer maximum as well, there are about 7,000 millions to the square yard, so that the waters of the lake form a veritable living soup. Perhaps, outside of Bacteria, this is near the climax of productivity.

The same exuberant productivity is equally characteristic of many tracts of the open sea, where a vessel may steam for days through floating meadows, several feet deep, of simple vegetation—mostly consisting of unicellular Algae. Thus clusters of threads, called *Trichodesmium*, may collect on the surface in calm weather, like unmelting yellowish-brown snowflakes, and extend over many acres. In an ordinary sample from a warm part of the Atlantic and from a depth of 50 metres (which is the most densely peopled zone as far as plants go), there are likely to be about 5,000 plant-cells in a litre; but there may be as many as a quarter of a million, which is a prodigious exuberance of life.

Number of Species.—There might be great abundance of life and yet no conspicuous variety, but every one knows that the number of different kinds of animals and plants is far beyond what we can readily conceive. Aristotle recorded about 500 animals, but a single expedition nowadays may still discover more than a thousand new species—most of them rather small deer we must admit. We are amazed at the number of stars which we can see definitely on a clear night, perhaps four thousand altogether, but there may be more species in one family of insects.

In the small island of Britain there is a record of the

occurrence of about 462 different kinds of birds, and the total number of living species of birds may be safely estimated at not less than ten thousand.

Dr. Gadow, writing in 1898, estimated the number of recent species of Vertebrate animals at 24,241. He put Mammals at 2,702, Birds at 9,818, Reptiles at 3,441, Amphibians at 925, Fishes at 7,328, and primitive Vertebrates at 27. But it is when we pass to the Invertebrates that the numbers of species mount up so enormously. Thus an authority on Diptera has put the probable number of species at a hundred thousand, and there is no doubt that there are many times more species of insects than of all other animals put together. Dr. Sharp remarks that though the largest insects scarcely exceed in bulk a mouse or a wren, ' yet the larger part of the animal matter existing on the lands of the globe is in all probability locked up in the forms of Insects '.

The same authority estimates the number of named species of insects at 250,000 ; and suggests that this is only about a tenth of the total. It has been estimated that there are about 200,000 plants, of which about a half are Dicotyledonous Flowering Plants. But even more impressive is Darwin's record of finding twenty species of Flowering Plants in a patch of turf four feet by three ; or the finding of four hundred in a square mile.

Variety of Form.—There are not very many main styles of architecture among animals, but there is endless variety in detail. All the Vertebrates are obviously reducible to one style of architecture, but what contrasts there are between eagle and whale, between tortoise and snake, between eel and skate, between frog and newt, between swift and penguin, between weasel and giraffe, between minnow and

man, and so one might continue for a long time. Among Invertebrates, the unicellulars or Protozoa form a sub-kingdom by themselves; the Sponges and Stinging Animals ring the changes on the possibilities of radial symmetry; Worms present a bewildering variety of types with little in common save the general tendency to be 'worm-like'; Echinoderms, though a very well-defined series, show astonishing contrasts,—between brittle-star and sea-urchin, between the sausage-like sea-cucumber and the graceful sea-lily. The two other great series are the Arthropods and the Molluscs, sharply contrasted at almost every point. Among Molluscs we may compare oyster with cuttlefish, slug with nautilus, land-snail with 'sea-butterfly'; it is difficult for the ordinary observer to understand on what grounds such dissimilar forms can be united under one title. Similarly, the exceedingly successful Arthropod series, rivalled only by the Vertebrates, includes Crustaceans, Centipedes, Insects, Spiders, Scorpions, Mites and many other very divergent types. If we consider Crustaceans, we get the same impression,—water-fleas and lobsters, fish-lice and land-crabs, sand-hoppers and barnacles—what a variety of form! The crowning illustration is surely among Insects, where within a relatively narrow range we find an astonishing wealth of style,—the squat bug and the lank walking-stick insect, the heavy beetle and the dainty midge, the butterfly and the flea, the mosquito and the cockroach. It has also to be remembered that there are many less familiar types of animal life which represent quite distinct lines of their own, such as Rotifers, Polyzoa, and Brachiopods, which greatly increase the range of diversity of forms.

Variety of Bread-Winning.—In illustration of variety of habit, let us recall for a moment the variety of food-

getting among birds—the blackbird gobbling the belated worm in the early morning, the thrush making a 'kitchen-midden' of snail shells, the humming-bird sipping nectar from the flowers, the oyster-catcher jerking the limpets off the sea-shore rocks, the woodcock probing for earth-

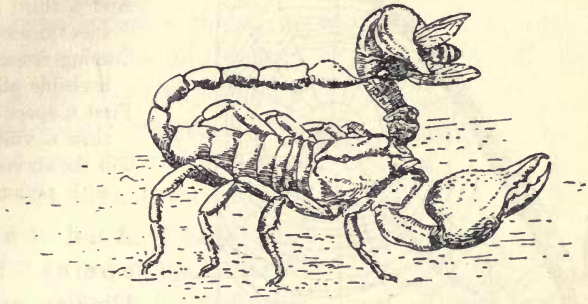


FIG. 3.—A Scorpion, Euscorpius, holding a fly in one of its claws, or pedipalps, and piercing it with its sting. (*After* Lankester.)

worms among the mould, the stately heron fishing by the side of the stream, the eagle in low flight searching the mountain-side for grouse, the secretary-bird striking the snakes in the South African karoo, the cross-bill deftly tearing up the cones on the fir trees.

It seems certain that vultures and the like discover their prey by sight and not by smell. Sometimes they seem to keep definite 'preserves' in the sky, and when one sees the carcass and descends upon it, his neighbour in the next 'preserve' follows suit, and another and another as the news passes through the heavens. A fine picture of this is given in *Hiawatha*—

> 'Never stoops the soaring vulture
> On his quarry in the desert
> On the sick or wounded bison,

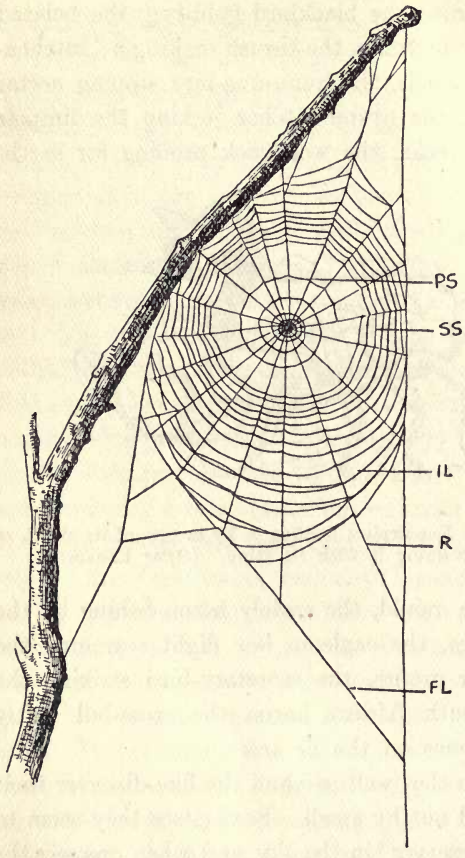


FIG. 4.—Web of Garden Spider. The spinner makes first the strong foundation-lines (FL). Then the rays (R) are made. Third, a non-viscid primary spiral (PS) is formed, as a scaffolding, from the centre outwards. Fourthly, this is replaced by the viscid secondary spiral (SS), which is the genuine web, made from the outside inwards.

But another vulture, watching
From his high aërial look-out,
Sees the downward plunge and follows,
And a third pursues the second,
Coming from the invisible ether,
First a speck and then a vulture
Till the air is dark with pinions'.

And then comes the blinding poetic flash—

'So disasters come not singly'.

There are humdrum ways of getting food, which the grazing herds illustrate. But how often this serious problem is solved dramatically! Every one has heard of the Archer or Spitting Fish (*Toxotes*) of Malay, which shoots

from its mouth a long jet of water and with accurate aim secures a coveted insect which was sunning itself on the plants overhanging the stream. The larva of the ant-lion digs a funnel-like pit in the sand and lurks at the foot to seize small insects that roll down; and the larval Cicindela makes a vertical tube, 'in which he props himself like a chimney sweep climbing up a chimney', so that his head forms a lid on the level of the ground. M. Henri Coupin describes the procedure: 'When a little creature is about to pass over this veritable living trap the larva sinks down, at the same time dragging with him his victim, which he hastens to seize between his claws and to devour'. Spiders' webs and snares illustrate another method which has often its detailed subtleties. Thus M. Coupin refers to Vinson's discovery of the use of a strong silken string bent in zigzag in the middle of the web of a Madagascar spider, which makes a construction very much like that of the common *Epeira diadema* of our gardens. The cable must be of use, for if it be removed it is at once replaced by another, but what can its use be? The answer was forthcoming one day when Vinson saw a large grasshopper jump into the web, and saw the spider hastily seize the cable and wind it round the unusual victim, who was too big to be held by the usual fine threads! There is such an embarrassing number of strange ways of getting food that it is difficult to pick and choose,—some

FIG. 5.—Garden Spider, Epeira diadema, female.

lurk like the crocodiles, some act burglar like the ant-eater bursting into the termitary, some hunt in packs and some alone, some utilize what others have won. Thus in the North of Scotland it is not an uncommon sight to see a Skua gull (*Stercorarius*) chivying herring gulls in the air until they disgorge their last caught fish. It is an astonishing fact that this should be sometimes re-caught by the skua before it reaches the water. What a long gamut there is between the behaviour of these skuas and the land leeches in the tropical forest! ' Only too frequently ', says M. Coupin, ' one hears a sudden noise like hail falling on the branches. It is not falling hail, but leeches, which hasten to attach themselves to beasts of burden and to men, from whom they proceed to suck the blood. They were watching [sic] their chance, perched on the branches—an odd dwelling-place, by the way, for creatures that are generally considered aquatic '.

We have referred in " The Biology of the Seasons " to Jacobson's extraordinary story of a mosquito milking an ant. For that is what it comes to. The mosquito frequents certain trees in Java on which the ants (*Cremastogaster diformis*) go to and fro. It hails a passing ant and strokes her head with quick movements of fore-legs and antennæ. Perhaps it tickles, perhaps it massages the ant—who can tell? It seems to please her anyhow, for she emits a drop of juice which the mosquito sucks up. The mosquito has been named *Harpagomyia splendens* by de Meijere, who points out that the creature cannot bite. But to beg it is not ashamed. Jacobson found two other Dipterous insects in Java which seem also to have learned how to tap ants. These extraordinary inter-relations recall the well-known but very remarkable fact that

several species of ants keep Aphides or green flies as their cows (*vaccæ formicarum* as Linnæus said), utilizing the sweet fluid which they exude when they are stroked. The ants take some care of the Aphides and resent interference with their property.

Milking ant or aphis is dainty feeding; contrast it with a python's meals. A specimen of *Python reticulata*, about 25 feet long, which was observed in Hagenbeck's zoological garden, swallowed a swan of 18 lb. and two days later a roebuck of 67 lb. Another swallowed within two days two roebuck of 28 lb. and 39 lb., and soon thereafter a chamois of 71 lb. In another case a goat of 84 lb. in weight was engulfed, and took about nine days to digest. The pharynx can be dilated to a width of over a yard. After a meal the pythons remain inert, and it should be noted that although they often eat much, they do not need to eat often! Two of them remained in good condition from spring to November without eating at all.

The voracity of some of the Deep-Sea Fishes goes beyond

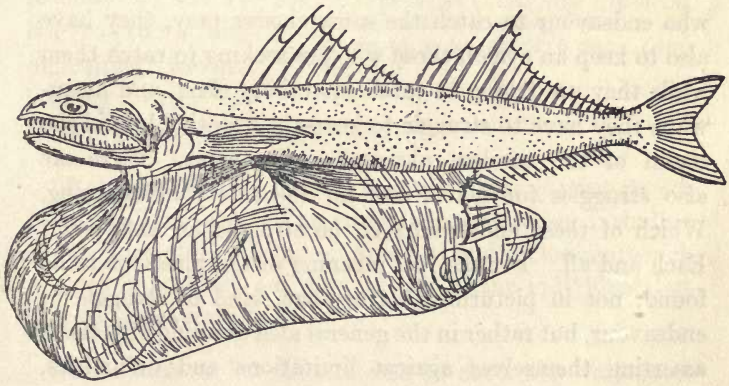


FIG 6.—A Deep-Sea Fish (Chiasmodon niger), whose distended stomach contains a larger fish. (*After* Günther.)

bounds. Thus it is recorded that the first specimen of *Melanocetus johnsonii*, obtained from off Madeira, had engorged another fish about twice its own length. Dr. Gill writes :—'The extensibility of the jaws and connected parts as well as the dilatability of the œsophagus, stomach and integuments enabled the captor fish to accomplish this feat'—after which it took a bait and was caught. Another curious fish, *Linophryne lucifer*, from the same locality, came to be known by coming up to surface, hoist on its own petard, having swallowed another fish longer than itself.

The Struggle for Existence.—As we watch the drama from year to year we see ever-recurrent situations. The dramatis personæ may be different, but the situation is the same. Among the most familiar of these situations are the various forms of 'the struggle for existence', which we use as a formula to include all the ways in which living creatures *react to limitations* :—Animals get hungry, they seek their food, they endeavour to catch what often endeavours not to be caught, they compete with others who endeavour to catch the same elusive prey, they have also to keep an eye on those who are seeking to catch them while they are trying to catch something else ; and meanwhile they have to struggle to keep their foothold amid the storm of the careless physical environment. There are also struggles for mates and for the safety of offspring. Which of these endeavours is the struggle for existence ? Each and all. For the real meaning of the phrase is to be found, not in picturing this or that kind of struggle or endeavour, but rather in the general idea of living organisms asserting themselves against limitations and difficulties, partly no doubt due to their immediate competitors of the

same kin or even family, but by no means restricted to this.

It is important to realize the variety of 'struggle'—from a life and death competition around the platter of subsistence to a persistent and peaceful endeavour after well-being. It may be for foothold, for food, for mates, or on behalf of the family. It may be (1) between fellows of the same kind, (2) between foes of quite different kinds, or (3) between organisms and their physical surroundings, i.e. between Life and Fate. In insisting on this multiplicity of 'struggle', or reaction against limitations and difficulties, we are keeping close to Darwin's own meaning, for he wrote :—

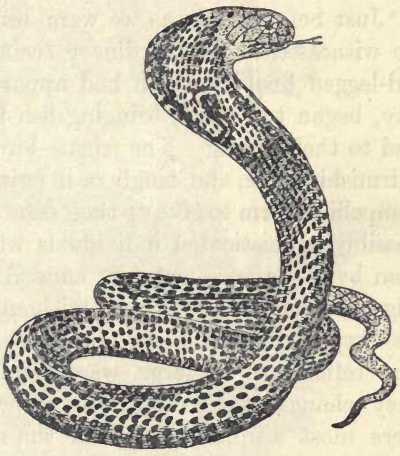


FIG. 7.—Spectacled Cobra, *Naja tripudians*, in the act of striking. The animal grows to a length of 5 feet. (*After* Fayrer.)

'I should premise that I use this term ['struggle for existence'] in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny.'

Let us take a few illustrations to show the variety of 'struggle'. The competition between antagonistic species

and indirectly between members of the same species is vividly pictured in an account which Mr. Dean C. Worcester gives of a recent visit to Cavilli Island, one of the Philippines. The actors were the red-legged boobies (*Sula piscator*), related to the British gannet, and the frigate-birds (*Fregata aquila*).

'Just before dusk, as we were leaving for the steamer, we witnessed an extraordinary scene. Large numbers of red-legged boobies which had apparently been fishing all day, began to return, bringing fish to their nesting mates and to their young. The frigate-birds promptly formed a skirmishing line, and, singly or in pairs, attacked all comers, compelling them to give up their fish. Some of the boobies, possibly sophisticated individuals which had learned wisdom by experience, actually handed their fish over to the frigate-birds and so escaped without much drubbing, but less experienced or more obstinate individuals, which at first refused to disgorge, were vigorously punished until they changed their minds and threw up their fish which were most adroitly caught in the air by their piratical enemies. In one instance, two frigate-birds set upon a booby, one of them attacking him from above, and the other flying below to catch the fish which he dropped, and getting five out of seven. Soon the incoming boobies began to arrive in flocks, and the frigate birds were not able to set upon them all, so that many individuals got through to the island. Once among the trees they were left in peace.'

Captain A. R. S. Anderson has given us a dramatic picture of an extraordinarily keen, though somewhat one-sided, struggle between birds and bats. The scene is in the Far East by the banks of the river Salween, where lime-stone rocks rise for some 250 feet, and are bored by caves and ornamented by Buddhistic sculpture. The human tenants are

FIG. 8.—Large Bats, Noctules, Vesperugo noctula, clustering on an old tree.

long since sped, and the caves are the home of legions of bats. As the sun is setting a couple of falcons come over the hill and fly restlessly to and fro over the river, keeping a watchful eye on the mouths of the caves. Then kites and jungle crows gather together till there are about a hundred. The dramatic moment is at hand. Out comes a single bat, then a pair, in puzzling jerky flight, eluding the birds of prey, who are too experienced to be led off on a profitless pursuit. There is a pause for a minute or two, then a sudden rush of wings is heard, and the nightly sortie begins. Like smoke from a dirty chimney on a stormy day, the bats issue in a dense column, ten feet wide by ten feet deep, in hundreds and thousands, so closely packed that many are jostled into the river below. The falcons, kites, and jungle crows have now their innings; they fall upon the sortie and, striking right and left, soon obtain all they want. But the enormous majority of the bats escape safely into the after-glow. It seems likely that the ceaseless sifting process is automatically regulated, else the relatively weak and slowly reproducing race of bats would long since have come to an end. Bats have such an unpredictable kind of flight that they are very difficult to catch; when the birds reduce their numbers so that the crowd is no longer closely packed, the nightly percentage of victims will fall. It will no longer pay the birds to hunt them, and there will be a close time till the numbers rise again.

A New Jersey naturalist describes a great host of mosquitoes, which were pursued and thinned by a large army of dragon-flies, which were being in turn destroyed by a big flock of birds. Similarly in mankind, while one tribe is destroying another a more civilized power often bears down upon the conquerors. We have referred elsewhere to

Mr. Hudson's very instructive picture of a wave of life in South America. Fine weather and many blossoms; many flowers and many bees; many bee-grubs and many mice; multitudes of mice and a thronging host of birds of prey. Diets are changed, habits are changed, numerical proportions are changed; and then—the season suddenly changes, and everything collapses with terrific mortality into a new position of equilibrium.

Rotifers, or Wheel-animalcules, are microscopic, but the struggle for existence is as keen as among rats. Most eat single-celled plants and animals; some pierce the cells of Algæ and suck out the living matter; and some swallow other Rotifers whole. Mr. C. F. Rousselet, whose beautiful microscopic preparations of Rotifers are deservedly famous both in Europe and America, has told us of the cannibalistic voracity of *Ploesoma hudsoni*, which seems actually to have a predilection for its own kith and kin. 'Of all Rotifers this is the most vigorous swimmer; it rushes through the water at great speed, snapping at any other Rotifer that comes in its way, carrying it in its mouth and devouring it without a moment's pause'. 'The attacking individual snaps at and holds on to its victim like a bull-dog', it pierces the skin and sucks up the soft parts. One of Mr. Rousselet's slides showed three of these 'atrocious cannibals': 'the anterior individual is being carried in the jaws of its captor, whilst the latter has been caught a moment later by a third *Ploesoma*, intent on devouring both'. We have here a good instance of the frequent intensity of the struggle for existence.

Thrust and Parry.—We get a side-light on the struggle for existence when we observe the prevalence of armour and weapons, and all manner of defensive and offensive

devices. We say ' armour ', and we see armadillos in their bony mail, giant sloths with shields an inch in thickness, tortoises almost invulnerable, scale-clad fishes, molluscs in their shells, crustaceans and insects within their strong chitinous cuticles, sea-urchins bristling with heavy spines like hedgehogs,—the stage is full of men at arms.

We think of ' weapons ', and what a collection rises into view, from the microscopic stinging threads of the jelly-fish and the Portuguese man of war to the tusk of the male narwhal, ten feet long, from the forceps of crabs to the antlers of stags, from the stings of bees to the fangs of the cobra, from the lashing tail of the sting-ray to the sword of the sword-fish, from the strangling arms of the octopus to the talons of the eagle !

But stopping an endless catalogue, let us take three or four instances of the quaintness of methods of offence and defence.

In the case of the common nettle, the sting is effected by specialized hairs, each of which shows a bulbous base with glandular cells, a slender stalk with a duct running up it, and a sharp-pointed ' cap ' at the end of the brittle tip. The sharp tip pierces the skin, and in breaking off there effects an injection of the poisonous secretion. In the hair of the Chilian nettle (*Loasa*) there is no cap to the hair, the tip is sharp-pointed and like a curved needle.

A very curious means of defence is seen in a number of Holothurians, or sea-cucumbers, which discharge long glutinous threads, or ' Cuvierian organs ' from the posterior end of the body. In *Holothuria nigra*, the Cuvierian organs are white conical bodies which are protruded posteriorly, when the creature is irritated. They remain attached by their bases to the animal, but elongate into long glutinous

tubes which become disconnected. The elongation is due to internal fluid pressure and is always preceded and accompanied by a rise of pressure in the fluid of the body-cavity. A lobster of considerable size may be bound hand and foot with these threads of the 'cotton spinners', as some of the Holothurians are called, a quaint instance of an animal with a highly developed nervous system being ensnared by the retaliations of a creature which has not a ganglion or nerve-centre in its whole body. How dim its awareness of the situation must be!

As Dr. Theodore Gill observes, the capture of fishes by a lure began long before man acquired that art, it was evolved among fishes themselves. The angler (*Lophius piscatorius*) has a dorsal fin-ray turned into a rod and line and dangling bait. 'It needs no hook, for the bait attracts a victim sufficiently near to be seized upon by the sudden leap of the angler'. The dangling of the bait is quite automatic, and the device probably began fortuitously, but the angler is very alert. In some Deep-Sea anglers there is, in addition to wormlike baits, a phosphorescent bulb or lantern which is perhaps seductive.

Many butterflies, especially from warm countries, have the power of exhaling a repulsive odour. Dr. F. A. Dixey mentions Acræa, Euploea, and Papilio as genera among which this property is common. 'Musty straw, stable litter, rabbit-hutches, acetylene, bilge-water, these are some of the substances to which the odours of these unsavoury butterflies have been compared'. The odour may be distributed from patches of specialized scales or hairs, or from the general wing surface, but never from plume-scales such as distribute the delicate flower-like perfumes. Moreover the scents occur in both sexes and may be stronger

in the female. There is much actual evidence that the repulsive odour protects the butterflies from insect-eating enemies. Dr. F. A. Dixey notices that many of them are conspicuous, slowly-flying forms, given to courting observation rather than to avoiding it. They trust to their repulsiveness.

'Moreover since it is well recognized that the preservation of the life of the female is more important than that of the male for the welfare of the species, we should expect that if there is a difference between the sexes in the intensity of the odour, that difference would be in favour of the female. This, again, is borne out by observation in a number of cases. Where both sexes are repulsive, the female, as a rule, is the more repulsive of the two, and therefore (as a consolation) the safer from attack.'

Many Inventions.—In the higher reaches of the animal kingdom we find examples of deliberate device—the cat watches for the mouse, or the fox for the rabbit, the elephant bides his time and has his revenge after many days, the wolves encircle their victim and close in upon him; wits are pitted against wits in the battle of life. At lower reaches we find instinctive inventions which work extraordinarily well, but which do not seem to require any deliberate control. It is possible that they are suffused with awareness, but their efficient performance depends on the inherited organization of the nervous system. The insect 'feigning death' is certainly not consciously trying to efface itself; the crab that covers itself with a disguise of foreign objects is not clear as to its own device (we shall discuss the case later on), for it has been known to put on a *transparent* cloak with which the experimenter provided it. In many cases, doubtless, intellectual pro-

cesses which have their seat in the higher centres of the brain may come to the aid of the inborn instinctive processes which are localized in lower centres. And apart altogether from intelligence and instinct there are many striking cases of what may be metaphorically called successful inventions or 'shifts for a living', which depend on structural peculiarities of the organism gradually perfected through the ages. Without seeking to analyse at this stage, we wish to notice some of these life-saving and life furthering adaptations of structure and behaviour, which it is one of the charms of Natural History to discover. Just as in the human drama we see disguise and mask, imitation and bluff, underhand devices and clever escapes, so it is in the animal world, though the psychology of the matter is in most cases entirely different.

Over and over again in the history of animal life the situation has been saved by some thorough change (which doubtless took time to effect) in habitat or habit. The earthworms, springing probably from an aquatic stock, discovered the subterranean world, and must have enjoyed a prolonged golden age beneath the ground, until centipedes, burrowing beetles, and eventually moles came to trouble them in their deep retreats. A temporary prosperity must have likewise rewarded the invasion of the air by insects, —until flying reptiles, birds, and bats discovered the secret as well; or the adoption of a marine habit by the ancestors of our modern Cetaceans, Pinnipeds, sea-turtles, and sea-snakes. What success must have rewarded the birds' discovery of migration, or the hibernating mammals' very different device of evading the hardships of winter! In hundreds of different ways, at point after point, life has saved the situation by a change of tactics.

A general resemblance to surroundings is often life-saving, and one must not be in haste to exclude the possibility that some animals actively seek out the surroundings with which they best harmonize. With certain backgrounds a woodcock or a curlew upon its nest fades into its surroundings and becomes practically invisible, just as does the brown lizard on the sand, the green snake among the branches, the transparent arrowworm in the sea, the mountain hare among the snow, the hare on the ploughed land,—and one might fill a page with good examples.

It has been noticed that a grey donkey in a field at night may be quite invisible at a distance of a few yards, though the noise of its cropping is very distinct. On a night with diffused ground light, when cows were visible at a distance of eighty yards, a donkey was quite invisible at eight. It is probable that his lighter under-surface served to diffuse what light there was. A careful observer writes :—

'On his starboard quarter at four yards distance, his dark head appeared as a moving blur, but "stern on" at that distance he was completely invisible—an "airy nothing"—though, like Polonius, "at supper". It was most extraordinary to hear the animal feeding and to be unable to see a vestige of him.'

There is an interesting moth, the Golden-Eight moth (*Plusia moneta*), which during the last half-century has been spreading westward and southward from its Russian headquarters. Its first appearance in Britain was in 1857 ; a great invasion occurred in 1890 ; since then it has diffused itself over England. It is called 'Golden Eight' because of the markings on its golden-grey wings. When it is at rest, however, it puts on the mantle of invisibility and

strongly resembles a dead and dry leaf still attached to the stem. Mr. Charles Nicholson writes :—

'The front legs are stretched out straight in front of the head at a right angle to the axis of the body, the second pair of legs being pressed close to the body, while the last pair just hold to the support, almost, or quite, covered by the tips of the fore wings which just touch beyond the body, the moth appearing to be clinging to its support by the front legs and wings only. It falls to the ground when touched.'

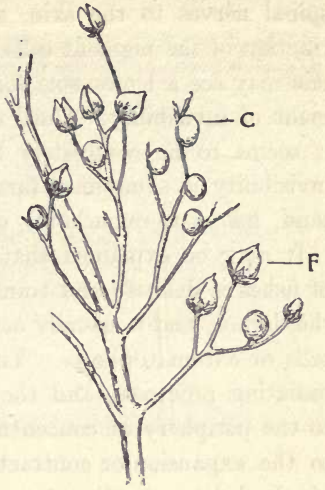


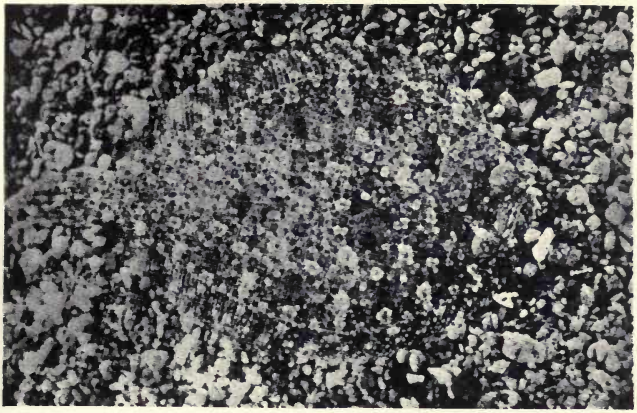
FIG. 9.—Piece of Figwort, *Scrophularia nodosoa*, with pupa-cases (C) of a beetle, *Cionus scrophulariæ*, with a marked superficial resemblance to the fruits (F).

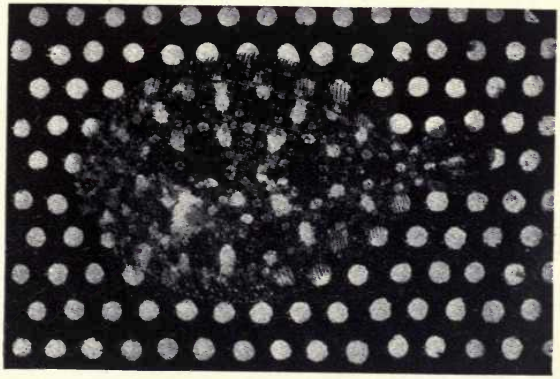
The value of the protective coloration may be enhanced when it is associated with a power of colour-change, when the animal, within certain limits, can adjust itself to the particular hue or even pattern of its surroundings. This is extraordinarily well illustrated by many of the flat-fishes, of the plaice, flounder, sole series, which can adjust the shade and the pattern of their upturned surface so that they become practically part and parcel of the sand or gravel on which they are resting. It appears that the colour of the surroundings first affects the eye, then the brain, then the sympathetic nervous system, then the

spinal nerves to the skin, and finally the state of contraction of the pigment cells just below the surface. Any one may see a lemon-sole, for instance, putting on its garment of invisibility. Until one catches sight of its eyes, it seems to be completely lost in its background. The invisibility is sometimes further ensured by a dusting of sand, but it is remarkably complete without that.

It may be explained that the outer skin or epidermis of fishes is delicate and transparent. All the colour is in the dermis, and it usually occurs in remarkable pigment-cells or chromatophores. These typically show numerous radiating processes, and the pigment can be spread out to the periphery or concentrated in the centre, according to the expansion or contraction of the mobile protoplasm of the pigment-cell. According to the pigment which they contain—black, yellow, red, and so on—the pigment-cells are called melanophores, xanthophores, erythrophores, and so forth. Then there are other cells containing spangles of the waste-product guanin, which are called iridocytes or guanophores. They cause the silvery, metallic, or iridescent appearance familiar on many fishes. Professor Ballowitz has recently discovered, in the Weaver and some other Bony Fishes, a new kind of chromatophore, consisting of a group of cells—a cluster of iridocytes with an encapsuled central melanophore which sends its ramifying process through the capsule in complicated courses.

The story goes that a chameleon, whose power of colour-change is famous, reached the limit of its capacity for 'sympathetic coloration' when it was placed in a tartan-lined box. It soon died, with a pained expression of baffled adaptability, but some of the achievements of flat-fishes in the way of harmonizing with their surroundings do not





fall far short of the tartan standard. We have inserted two illustrations which show how extraordinarily close the approximation may be.

The protective value of a colour-resemblance between an animal and its surroundings is probably increased when the form and pose of the creature is like something else. We do not, however, know very much in regard to the degree of attention which the enemies of these protected animals pay to form. As many animals appear to be alert in detecting movements of their prey, there will be an advantage if the latter are shaped like other things. A walking-stick insect that is creeping or swaying about on a twig, will be less likely to be seen as a moving object because of its strong form-resemblance to a group of twigs.

Here we have the well-known cases of butterflies like leaves, of caterpillars like little twigs, of spiders like lichens, and so on. It is interesting to notice that the perfection of the resemblance is often due to combination of items. Thus in the famous case of *Kallima*, which is like a pendent withered leaf when it settles down, usually head downwards, on a branch, there is similarity in colouring, there is resemblance in shape, the mid-rib and veins of the leaf are counterfeited by the nervures of the wings, the likeness is heightened by marks on the wings which look like fungus marks on the leaves, and so on. Moreover, in *Kallima* there is much individual variation in the markings on the under surfaces of the wings, ' simulating all degrees of decay and discoloration and fungus attack '. It seems reasonable to suppose that this variability of pattern is even more effective than if the *Kallima* were tied down to resembling only one kind of withered leaf.

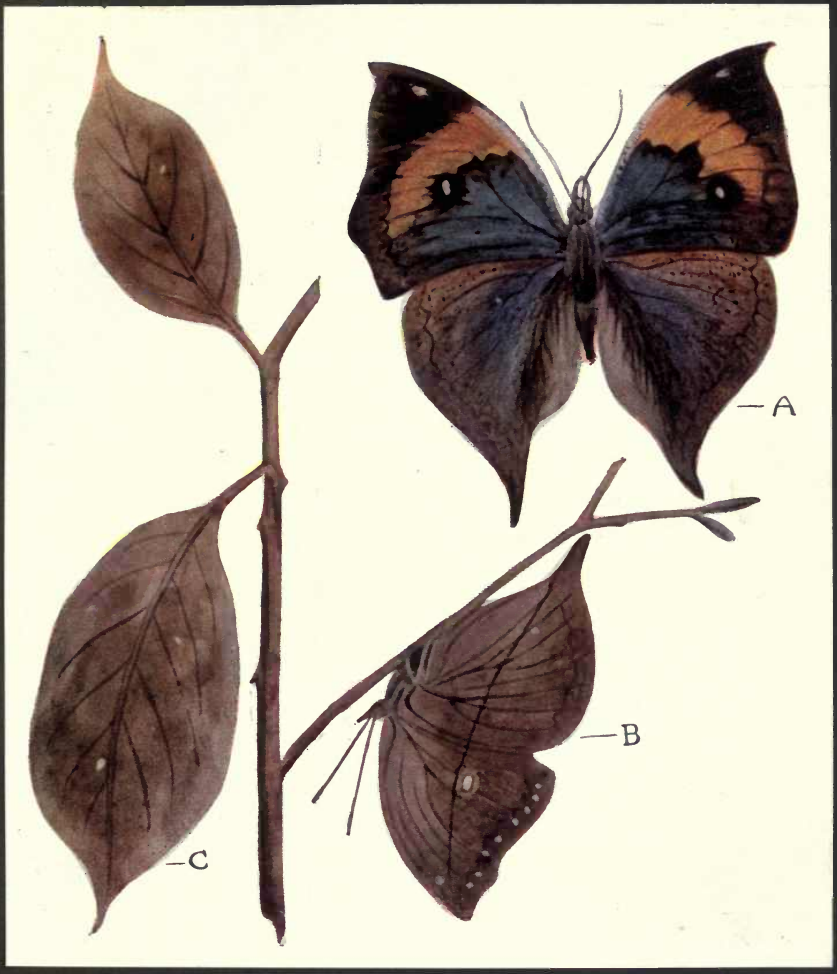
Subtlest of all these misleading resemblances to other

things is *mimicry* in the strict sense, where there is a striking external resemblance between two unrelated animals which frequent the same haunts. As examples we may cite the resemblance between the drone-fly (*Eristalis*) and a bee; between the European grass-snake, *Tropidonotus viperinus*, quite innocent in character, and a viper; between the Lepidopteron *Trochilium apiforme* and the hornet; between a spider (e.g. *Myrmarachne formicaria*) and the dreaded ant.

It is usual to refuse the title of true mimicry unless it can be shown (or unless it has been shown in analogous cases) that the mimicker lives along with the mimicked to a considerable extent, that the mimickers are in the minority, that the mimickers are like the mimicked in superficial characters only, and that the mimicked are more or less markedly safe and usually more or less conspicuous. It goes without saying that the use of the terms mimicker and mimicked is entirely metaphorical, for the mimetic resemblance is not deliberate.

Students of mimicry are accustomed to distinguish several types. Thus in 'Batesian Mimicry', first clearly defined by the naturalist-traveller Bates, we have a palatable animal escaping in virtue of its superficial resemblance to unpalatable forms, with striking features, which are rarely attacked and are greatly in the majority over the mimickers. The bad reputation of ants gives a vicarious safety to several ant-like spiders; the disagreeable taste of the mimicked butterfly helps the survival of its palatable Doppel-Gänger.

Mr. Guy A. K. Marshall observed a Dipterous fly, *Ceria gambiana*, visiting flowers in company with a formidable wasp, *Polistes marginalis*, and it seems reasonable to infer that the fly profits by its likeness to the dangerous creature


A
B
C

with a bad reputation that it has come to associate with. In all such cases single observations are unconvincing, but when similar cases accumulate the argument gathers force. Thus it is very interesting that J. Bourgeois should have noticed *Ceria conopsoides* visiting the wounds on the trunk of a horse-chestnut in company with a wasp, *Odynerus crassicornis*, a formidable insect. Both were visiting the tree with the same end—to lick the exudation; the fly was probably protected from certain enemies by its 'Batesian mimicry' of the wasp.

Another type of mimicry is called Müllerian, after the naturalist Fritz Müller, and here we have a resemblance between several immune species living in the same country. This is well illustrated among South American Lepidoptera, e.g. Danaids, Heliconids, and Acræids, and it seems to work like a sort of mutual assurance. None are palatable, but by being like one another they spread the risk of being experimented on by inexperienced birds. Birds have to learn discretion in their youth; they take many an unpleasant bite of unpalatable victims before they become proficient; they remember the marks of bad taste, and the more similar these marks are the more likely their possessors are to escape. The more in the ring, the less the waste of life.

There are many difficulties in connexion with mimicry—especially perhaps the question of its evolution—but it is difficult to see the remarkable illustrations collected by Professor Poulton and to consider the facts he adduces as to its efficacy in certain cases, without being ready to admit that it plays a considerable and curious part in the drama of animal life.

Sometimes the mimicry is very exact as regards colouring and pattern; sometimes it is rather in pose and movement.

Let us take an instance. From a pale emerald-green nest, sent from the Gold Coast to the Zoological Society in London, there emerged a crowd of young Mantids, about four millimetres in length, which exhibited a curious mimicry. 'When crawling about the case they looked exactly like a crowd of busy ants, their rapid darts and pauses recalling irresistibly the busy method of progression so characteristic of these Hymenoptera'. Now, there is nothing more profitable for an innocent little insect than to be like an ant, for ants have a very bad reputation, or what corresponds in the animal world to a reputation. But the interesting point which was noticed by Mr. R. I. Pocock, the Superintendent of the Gardens, was this, that it was only when they were moving about that they resembled ants. When they settled down they were seen in their true colours—as Mantises, 'raising the fore part of the body and head, folding up their fore-legs, and every now and then swaying gently from side to side as if rocked by the wind. While thus employed they were seen to be procryptically coloured'. That is to say, they were inconspicuous. This is obviously a very interesting case; when the little creatures were resting they were hidden, and when they were poking about they were like ants! Without observations and experiments in their natural surroundings no naturalist could assert that the young Mantises are saved from elimination by being inconspicu-

Fig. 12.—Spider, Synemosyna formica, like an ant. (*After* Peckham.)

ous or by being like ants. But as we have experimental proof in a few analogous cases, it seems quite sound Biology to say that these little Mantises probably get on very much better because they have added to the usual inconspicuousness of their kind, the additional advantage of being like ants when they are young. For by the time they had attained a length of seven millimetres, they had lost their ant-like look.

Another 'device' is that of masking, where the creature disguises its real nature by covering itself with foreign bodies. It is difficult to draw the line between extrinsic armour and disguise. Thus the larval caddis-insects in the streams cover themselves with minute pebbles or with pieces of plant-stem and the like; and this is probably in the main a protection, not a mask. When we pass to crabs covering themselves with sea-weed, or with sponge, or with hydroids, or with part of a sea-squirt's tunic, we have to do with something nearer masking.

Zoologists are well aware that the little crabs of the genus *Cryptodromia* are in the habit of masking themselves with pieces of sponge or ascidian or the like. R. P. Cowles has recently watched the whole process of sponge-cutting. The naked crab (*Cryptodromia tuberculata*, in the Philippines) cuts a groove on an encrusting grayish sponge, works its way under it, and dislodges it. In a short time the ragged edges of the sponge shield grow smooth and neat. The cutting is done with the forceps, but the dislodged piece is caught hold of and carried by the last pair of legs.

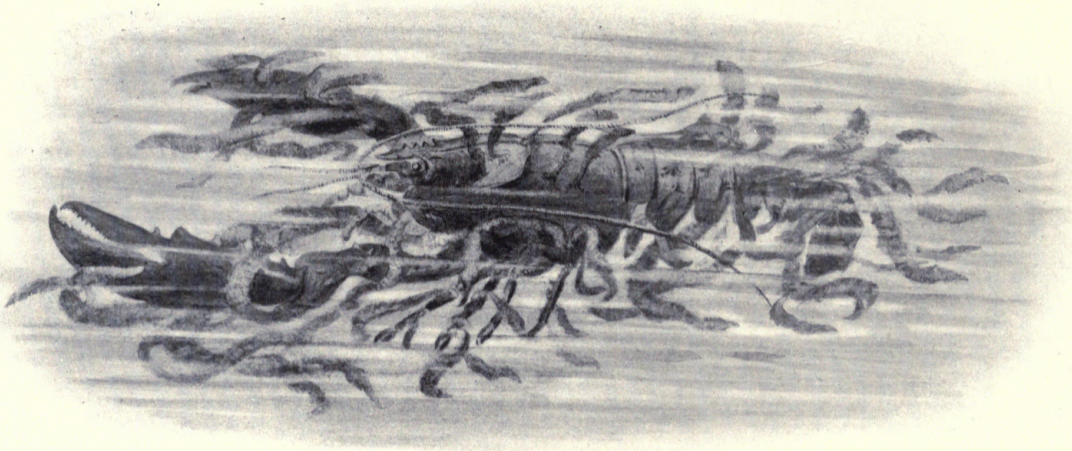
'It is a surprise to the collector when, on turning over a rock covered with large and small patches, he sees some of

the smaller patches suddenly become animated and crawl away. Another surprise is in store for him when he picks up one of these small patches and finds it to be the cover of a crab carefully hollowed out so as to fit the outline of the carapace, and tightly held in place by the last pair of legs, whose dactyli [terminal joints] are hooked into the inturned rim.'

Mr. Cowles also describes the way in which the Pistol Crab (*Alpheus pachychirus*) of the Philippines makes its tube of matted Alga-threads. The tubes, which are rather shelters than masks, are often 25 to 30 centimetres long and 2 centimetres in diameter, and one end is fixed to the rock. A male crab placed on a piece of matted Alga turned itself on its back, and using the slender chelate limbs immediately behind the forceps, drew the sides of a furrow together and sewed them by a simple stitching. Threads of Alga were drawn from each side into the opposite side. On another occasion a tube was torn into shreds and given to a pair of crabs, who made a coherent tube by next morning. Filaments were entangled on the edges of a sheltering piece of rock and then drawn together.

'When the Alpheus found a hole in the rapidly forming tube, the slender legs came through, caught hold of the filaments of the Alga, and manipulated them in much the same manner as a man might the thread with which he darns a hole in his sock; that is, by drawing the edges of the hole together and fastening them.'

Self-Advertisement.—In great contrast to those animals that walk delicately, or lie low, or fade into their surroundings, or put on disguise, there are those that are noisy and bold, fussy and conspicuous—the self-advertisers.



The theory is that those in the second set can afford to call attention to themselves, being unpalatable or in some other way safe. To *prove* a theory of this sort is impossible, but it becomes cogent and convincing in proportion to the number and variety of cases to which it can be applied.

Mr. Pocock, of the Zoological Society's Gardens in London, has applied the theory to various Mammals, and it seems to work out well. Taking the common shrew (*Sorex vulgaris*), for instance, he points out that it is fearless and careless,

FIG. 14.—The rattle of the rattlesnake (Crotalus), composed of a number of horny bells, added to at successive moults. It is agitated when the snake is excited and produces a shrill noise. Thus large animals, on whom the snake would simply waste its poison, are warned off.

and that it makes a frequent squeaking as it hunts. It can afford to be a self-advertising animal because of a strong musky scent, which makes it unpalatable. A cat will never eat a shrew. The odoriferous glands are situated in a long line on each side of the body. Similarly, the large Indian musk-shrew (*Crocidura cærulea*) is conspicuous even at dusk, quite fearless in its habits, and goes about making a peculiar noise like the jingling of money. But it is safe in its unpleasant musky odour.

The common hedgehog is comparatively easy to see at night; it is easy to catch, because it stops to roll itself up, on very slight provocation sometimes; it rustles about in

the herbage and ' sniffs furiously ' as it goes ; it often calls to its mate ; it is at no pains to keep quiet. Nor need it, for although a few enemies manage to eat it, the spines are in most cases quite effective prevention. Moreover, it can give rise when irritated to a most horrible stench. The porcupine is another good instance of a self-advertiser, and so is the crab-eating mungoose (*Mungos cancrivora*).

In a few cases we have some definite knowledge in regard to the actual process of adaptive colour-change. The spotted salamander (*Salamandra maculosa*), with its conspicuous livery of bright yellow and dark brown, is a case in point. It is well known to become almost black when the soil of its vivarium is dark and relatively dry. Two things happen : the yellow areas become gradually smaller, retreating towards the centre till they disappear ; and the dark areas become darker. Experiments following the ordinary method of exclusion are very instructive, e.g., using a black-paper ground with the normal humidity. The shrinkage of the yellow spots is induced by the colour of the ground, while the darkening is brought on by increasing drought. An experimenter, Alois Gaisch, relates that he put a salamander into a vivarium with black peaty soil (which remained moist), and found it almost unrecognizable after three months. The yellow spots had shrunk, there were many black dots about their margins, and microscopic examination showed that the black pigment had abundantly invaded the yellow areas. Two other salamanders put in about the same time showed no change of colour, which seems to show that there are differences in individual susceptibility. If that be so, and if it had not to do with age or the like, we have an illustration of how a selective process might work. For if it were

a matter of great advantage that yellow and black salamanders should lose their yellowness in a black-soiled country, it is plain that the non-susceptible types would be eliminated, while the susceptible types would survive and multiply after their kind.

We are accustomed to think of the chameleon's colour-change in connexion with protection, but it seems also to have a distinctly repellent value. Mr. Cyril Crossland has given an animated account of a chameleon frightening off a fox terrier which attacked it. At first the reptile tried to run away, but that is not its strong point! 'In a few seconds the impossibility of escape seemed to reach the animal's brain, when it at once turned round and opened its great pink mouth in the face of the advancing foe, at the same time rapidly changing colour, becoming almost black. This ruse succeeded every time, the dog turning off at once'. Mr. Crossland points out that in natural

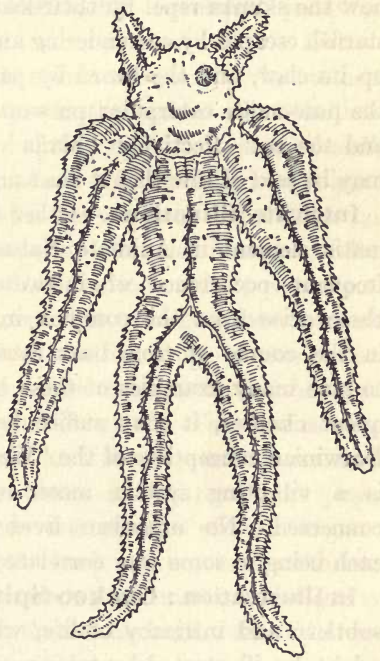


FIG. 15.—Common Starfish (*Asterias rubens*) regenerating lost parts. It shows at the top two arms which are just beginning to be regrown. The largest of the five arms has been previously regrown double. (*After* McIntosh.)

leafy conditions the startling effect would be enhanced—a sudden throwing off of the mantle of invisibility and the exposure of a conspicuous black body with a large red mouth.

There is no end to these effective adaptations, and all that we are concerned with here is the illustration of a very remarkable aspect of the drama of life. We know how cuttlefishes throw dust (or ink) in the eyes of their pursuers; how the skunks repel by their loathsome stench; how the starfish escapes by surrendering an arm, the crab by giving up its claw, and the lizard by parting with its tail; how the puss-moth caterpillar puts on 'a terrifying attitude', and the cat effectively 'bluffs' the dog. Of a truth it may be said of Life that it has sought out many inventions.

Intricate Situations.—Other illustrations of the dramatic element in Animate Nature may be found in the frequent occurrence of intricate situations. Many of these arise from the complex inter-relations which have in the course of time been established. As we propose to give many examples of these inter-relations in a subsequent chapter, it may suffice here to recall the general Darwinian conception of the 'Web of Life',—that Nature is a vibrating system most surely and subtly interconnected. No organism lives or dies quite to itself, each being in some way correlated with some other.

In Illustration: Cuckoo-Spit.—The impression of the subtlety and intricacy of life, which we wish to convey, might be illustrated by taking rare and quaint instances, but the commonest things, curiously enough, are always the most striking. In early summer in temperate countries nothing is commoner on the herbage than the splashes of white froth which are often called 'cuckoo-spit'. The

old idea was that the mother-cuckoo spat them out as she flew around looking for a suitable nest in which to place her egg, and it was also supposed by some that they gave rise spontaneously to singing Cicadas. They have, of course, nothing to do with cuckoos, but they have, in a sense, something to do with cicadas, for they are produced by the larvæ of insects, e.g. *Aphrophora spumaria,* which are related thereto. They are popularly known as frog-hoppers, in allusion to the highly developed jumping powers of the adults.

The eggs are laid the previous autumn by the mother 'froghopper' in deep crevices in the bark of willow-bushes or the like; they hatch in spring, and there emerge small squat larvæ with a piercing beak and firmly gripping legs. These probe the leaves and stems of plants and suck up the sugary sap, much as their relatives the green-flies or Aphides do. And just as 'honey-dew', as it is called, passes out of the food-canal of the green-flies in large quantities and smears the leaves and even falls like drops of rain to the ground, so the surplus sap passes through the frog-hoppers and forms the familiar foam-like 'spit'. The food is very abundant, the larva grows and moults, and grows and moults again, and finally passes into a resting or pupa stage; its wings grow and other changes of structure are brought about; it leaves the froth and moults for the last time; it becomes a full-grown winged insect, and there is no more foam to be seen on the herbage. All the frog-hoppers have grown up.

The making of the foam which envelops and conceals the larval frog-hopper is of much interest. In the first place, the material is watery sap, slightly changed by passing through the food-canal; it is exuded at the hind end and

spreads over the body and limbs. In the second place, there is an external air-canal, a sort of closeable gutter on the under surface of the body posteriorly, in which the insect collects air from the outer world and from which it can expel it into the surrounding clear fluid. If we watch carefully we can see the larva raising the end of its body to the surface of the froth and allowing the air-canal to fill; thereafter the canal is used like a pair of bellows and air is blown into the fluid. Some of the air is of course utilized for the insect's breathing. In the third place, there are minute wax glands on two of the segments of the hind part of the body, which produce small quantities of wax. This is acted on by a ferment in the exuded fluid and a sort of soap is formed! If it were not for this soap-production the bubbles would not last so long as they do.

It is a very remarkable device, living under water and yet in the open air, conspicuous and yet concealed, in the sunshine and yet cool! Though the frog-hoppers are sometimes picked out from their frothy shelter by audacious wasps and the like, there can be no doubt that they are saved from many enemies and many risks by having acquired the art of blowing soap-bubbles. For that is precisely what happens.

The Case of Horned Lizards.—Among terrestrial animals, the lizards stand easily first in the exhibition of quaint and bizarre forms. It seems as if Nature had, so to speak, let herself go among lizards in quips and cranks. How like a joke the chameleon and many another quaint lizard seems till we see them in their appropriate environment and at their daily work. We are thinking of forms like the little dragon (*Draco volans*), with its skin webbed between enormously extended ribs; or the Australian

moloch, with its curiously hygroscopic skin, pimpled all over with sharp tubercles; or the frilled lizard which Saville Kent describes, that runs totteringly about on its hind legs like a baby just before it falls; or the basilisk, with erectile crests on its back; or our own British slow-

FIG. 16.—Frilled Lizard (Chlamydosaurus) running like a biped, with its collar folded round its head. (*After* Saville Kent.)

worm, which has put on the guise of a snake, and is famous for the ease with which it can surrender its tail to save its life.

In the show of quaint lizards the chameleon must always be awarded the first prize; but many will agree with us in thinking that the horned lizards of Mexico, California, and Nevada come a good second. They have been known for a long time, but they have been made the subject of a recent monograph by Mr. Harold C. Bryant, of the University of California. To this fine piece of work—one envies the author his subject—we are indebted for some

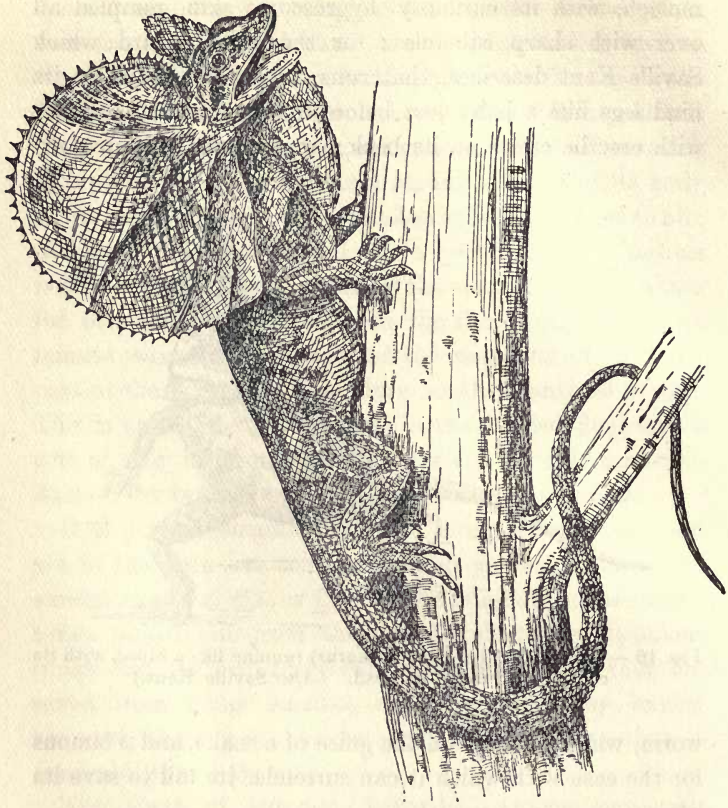


FIG. 17.—Frilled Lizard of Australia (Chlamydosaurus kingi) with a great erectile frill on the neck, folded when the creature runs, expanded when it stands at bay. The animal grows to nearly 3 feet. (*After* Saville Kent.)

new and interesting material. The creatures in question are often spoken of as ' horned toads ', the false classification being probably suggested by their squat shape, their sluggish ways, and their habit of catching insects on a sticky tongue. True lizards they undoubtedly are, and

among the Iguanids; but they differ from all other members of the order in their flat bodies covered with keeled, spiny scales, and in the circlet of horns upon the head. There are eighteen different species belonging to the genus *Phrynosoma*, and there is one other known, a unique creature from the deserts of the Gila and Colorado Rivers, which requires a genus (*Anota*) all to itself, and has the honour, indeed, of differing from every other living lacertilian in the closing up of a small gap on the roof of the skull known as the supratemporal foramen. One needs, however, to know a good deal about skulls before one can appreciate the importance of this unique feature.

What is the significance of the Phrynosome's peculiarities? In the first place, what is the meaning of that circlet of sharp horns on the head, which recall (as if in miniature) the projecting horns of some of the extinct Dinosaurs? The curious shape of head that results reminds one also of the quaint fruits of the water-chestnut which the peasants round Florence string into most decorative rosaries. But what are the horns for? They serve to ward off blows and bites, for the creature lowers its head and raises the scales of its back when it is on the defensive, and we can well believe that if an enemy bit the head of a Phrynosome once, it would never do so again. The Indians say that if a snake swallows one whole, the indomitable lizard proceeds to work its way by a short cut from the stomach outwards—which for the aggressor must be an extremely disagreeable process, bringing repentance to the snake. Mr. Bryant says that there is some foundation for this story, and it has its analogues at any rate in records of box-fishes biting their way out of sharks.

A second distinctive feature in the horned lizards is their

power of adaptive colour-change. They have the secret of the Gyges ring, and putting on the garment of invisibility is for them as easy as winking. ' Wherever its home ', says the monographer, ' the horned lizard resembles the colour of the substratum so closely that it is practically invisible except when in motion. Specimens from the white sand of the desert are very light in colour, those from the black lava belt are almost black, whereas those from the vari-coloured mountain districts show red and even bluish markings. How quickly a change of environment would bring about a change in colour is not definitely known, although Coues states that the change takes place in from twenty-four to forty-eight hours '.

Given horns and scales and the mantle of invisibility, the horned lizards are safe, and we are not surprised to learn that most of the species are represented by large numbers of individuals. We can understand now why they have such a wide geographical range from Canada to southern Mexico, and from the Mississippi to the Pacific coast; why they rarely bite; why they can afford to take things easily, basking in the sun and moving with leisurely deliberation. When an enemy comes they ' play 'possum '; when they are thoroughly scared they seek refuge in a bush or burrow in the sand.

Even in their burrowing they are unlike most other creatures, for they work their way beneath the ground head-foremost. As Mr. Bryant says, ' The chisel-shaped head is the principal tool, the legs being used almost solely for forcing the head forward. A wriggling motion of the head and body serves to drive the head beneath the sand and soon covers the body completely with earth. A little shake of the tail flings the dirt over that appendage,

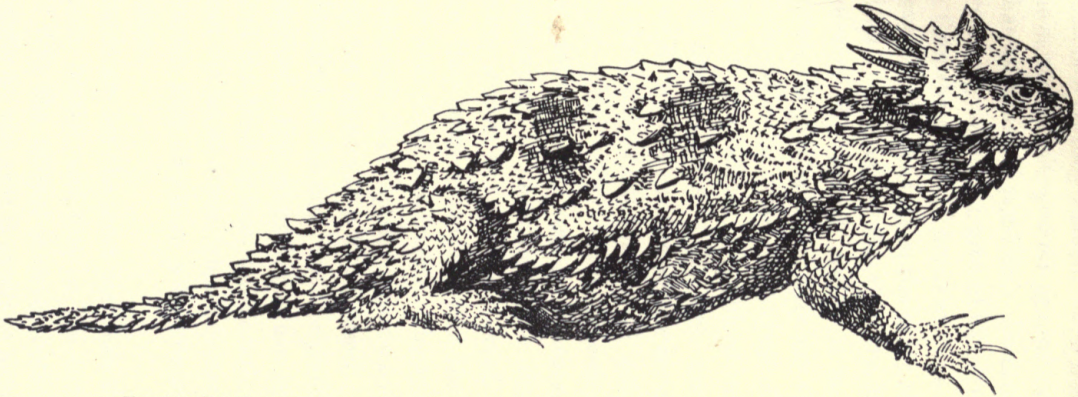
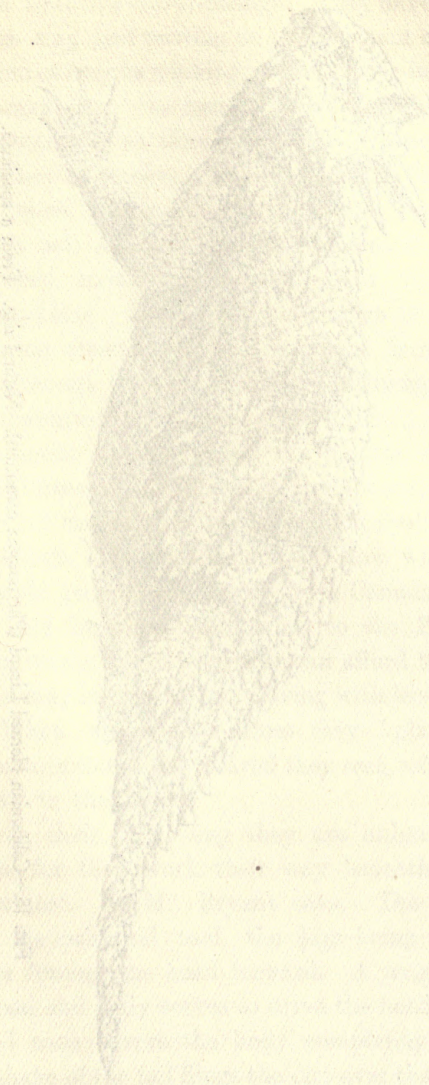


FIG. 18.—Californian Horned Lizard (Phrynosoma cornutum). Natural size. From a specimen.



and the lizard becomes entirely hidden. The nostrils are kept either at the surface of the ground or near enough to the surface so that breathing is possible'. Sometimes the spines are left protruding above the ground like dry thorns.

Stranger even than the circlet of horns and the wonderfully perfect power of colour-change is the habit of 'shedding tears of blood'. It was for this that the Mexicans called the Phrynosome the 'sacred toad'; it is to this that the boys of San Diego refer when they say they saw the creature 'spit blood'. As there are the best of physiological reasons why it can neither 'weep blood' nor 'spit blood', what is it that happens? The eyes are tightly shut, the eyelids swell to twice or thrice their normal size, and a fine jet of blood shoots out for several inches from beneath the upper eyelid. The whole phenomenon is startling and quite worthy of the strange creature. Some say that the hæmorrhage is associated with the excitement of the breeding season, but this lacks proof. So far as experiments go, they seem to indicate that the rush of blood is associated with shock and fright. The eyelids are rich in blood-vessels, and what happens is first a congestion and then probably the rupture of a blood-vessel. It may be compared to bleeding at the nose, but the point is that it has been regularized. One physiologist has suggested that the flooding of the head sinuses, the elevation of the blood pressure, and the jet of blood, while associated with panic and excitement, may also have a frightening effect deterrent to enemies.

The horned lizards are for the most part insectivorous, catching living ants, beetles, and flies on the end of the viscid tongue. 'Why the animal is never bothered by being stung internally by the ants it swallows alive seems

hard to explain.' It is sensitive enough externally; can it be that it is immune internally? When insects become scarce, and the cold weather sets in, the horned lizards burrow into the ground and pass into the coma of hibernation. Dr. Gadow makes the interesting note that if captive specimens are not allowed to hibernate, 'they will keep on feeding through the winter, but in that case are sure to die in the following spring'.

We may leave the horned lizards in their winter sleep, though without nearly exhausting their peculiarities. One more may be mentioned, which, like the hæmorrhage, well deserves further study. Mr. Bryant has found that they are very amenable to what looks like hypnosis. When a specimen is rubbed on the top of the head and between the eyes, it turns its head down, closes its eyes, and passes into a stupor, in which it may remain for five or ten minutes. But the observer was not quite sure whether what happened was a faint, or a feint, or neither. It presents one of those unsolved problems with which every study in Natural History should begin and also end.

Love-Scenes.—The interest of many a human drama is in its love-affairs—two men and a maid, two maids with their hearts set on one man—such are the apparently simple data from which a plot is evolved. And it is so among animals also. We need not quibble about words; the love of the Argus pheasant showing off his hundred eyes before his desired mate is doubtless very different from the love of the stickleback coaxing and driving his bride to the nest among the weeds, and both are very different from our loves, but there is undoubtedly a common element. We must avoid the amiable error of generosity—reading the man into the beast—but we must

avoid the opposite error of excessive stinginess which reduces the animal to the level of an automatic machine. The true view is between these extremes.

Among the loves of animals, we may find what is commonplace (when there is not the slightest hint of preferential mating), but we also find the extraordinary, as when a she-spider puts an abrupt full stop to a courtship by devouring her suitor. We find what provokes us to mirth, as when a male spider waltzes over a hundred times around his desired mate at a respectful radius; we find also what seems pathetic, as in the familiar nuptial flights of the ants, where the apparent waste of masculinity is so enormous—worse than the worst of wars.

Let us travel to the meadows around Bologna. It is late on a summer night, when the darkness is short. It is very quiet, for even the frogs have ceased for weeks to utter their cheerful brek-a-brek whose interrogativeness expresses the essence of conversation. There seem to be living sparks in the air and lesser lights among the grass. It is the courtship of Luciola—the Italian fire-fly. The lady-Luciolas are sedentary; the males fly about. When a female catches sight of the flashes of an approaching male she allows her splendour to shine forth. He sees the signal, and is forthwith beside her, circling round like a dancing elf. But one suitor is not enough, and the lady-Luciola soon attracts a levée. In apparently courteous rivalry her devotees form a respectful circle, flashes of light come and go, and eventually in the dead of night the coquette's choice is made. In the two sexes, Prof. Emery says, the colour and intensity of the light is much the same, but the luminous rhythm of the male is more rapid, with briefer flashes; while that of the female is more prolonged,

with longer intervals, and more tremulous—suggestive indeed of the contrasts among higher non-luminous creatures. The picture is dramatic.

Family Life.—Why do the people thus strive and cry? the poet asked, and the wise answer came: 'They will have food, and they will have children, and they will bring up the children as well as they can.' This is true for us; it is also true for animals, and there often is a dramatic element in nurture. The mind fills with all sorts of illustrations of parental care—the kangaroo placing her newborn babe—unable even to suck—into her skin-pocket; the mother crocodile who digs up the buried eggs when she hears the restless young piping their slender signal from within the egg—it would not be well to be born buried alive; the father frog (*Rhinoderma*) who carries the eggs and even the froglets in his croaking sacs, yet does not swallow them—and so on; down and down—to the skate-sucker that mounts guard for months over its egg-clusters laid in a shell, or the little brook-leech that bears about its young hanging on to the body. But there are instances in which the dramatic element is more apparent than in these.

Let us spread the wings of our imagination again and travel to some warmer clime—Africa, Australia, but preferably India—to some place where hornbills are at home. These birds, well known for the helmet on their head, are tree-lovers, except when feeding; though their bones are more pneumatic than those of most birds, they fly heavily and slowly,—most of them with a sound like that of a steam-engine in the distance; their characteristic note is between the bray of an ass and the shriek of a railway engine; they are somewhat indiscriminating feeders,—in many ways, in short, not very attractive. But in

one respect their behaviour excites our admiration—the behaviour of the male bird to his mate and offspring.

When nesting-time comes, a hole in a tree is found, and the wife goes in and shuts the door. From material which she has gathered or which her husband brings she walls herself in—literally 'barring the door weel'. Only a small opening—like the grille in the convent door—is left; perhaps it helps to keep snakes and other enemies out. Through the window, however, the father feeds her, knocking with his bill if she is not on the outlook; as he clings to the bark he is (if nature be not a mirage) obviously anxious about his charge; she sits safe minding her own business, he works hard bringing succulent fruit, or tender mouse, or juicy frog; curiously enough he sometimes casts up the lining of his gizzard with all its contents enclosed—a strange votive offering on the family altar. We are not surprised to learn that by the time the young bird is ready to emerge the devoted father and husband 'is worn to a skeleton'. The story is dramatic.

Complications.—There is a novel by Turgenief called *A Friend of the Family* in which are depicted some of the disadvantages attendant on the guest out-staying his welcome. But there are far more complicated problems involved in the habit many ants have of being hosts to beetles. To make the matter clear, a brief introductory statement must be made. Just as we have or may have in or about our houses five sets of living creatures—parasites like the homœopathist's leech whose name of flea it is impolite to mention, really inimical intruders like rats, more or less indifferent fellow-inmates like the death-watch, useful domestic animals like the cow, and pets like the cat, so ants may have in their nests parasites in the

form of mites, unfriendly intruders, indifferent fellow-tenants, occasional 'cows' (as Linnæus called the Aphides), and pets. These pets are usually Staphylinid beetles belonging to the family well-represented in Britain by the devil's coach-horse (*Ocypus olens*). Some of the Staphylinids are downright robbers and others are merely tolerated by the ants, but there is a third set (represented by the genera *Atemeles* and *Lomechusa*) to which the name of pet may be applied. These beetles are never found outside or at any rate very far from the ants' nests; they have patches of yellow hairs which seem to secrete some substance which the ants like to lick; they seem to be on very friendly relations with the ants, for they stroke them and get drops of honey from their mouths, and they will in turn disgorge some of their repast for the benefit of a hungry host. On the other hand, these friends of the family are not so innocent as they appear, for while with bended knee they will solicit a *bonne bouche* from their hosts, and while they like to sit among a crowd of ants as if exchanging the compliments of the season, they are on the sly eating up a good many of the ants' children —and that when their own are receiving food from the ants. And now we come to our precise point. Looking down—through Father Wasmann's eyes—on this quaint association of hosts and guests, we feel safe in saying that the presence of the beetles adds to the ants' sum-total of happiness, and yet we cannot avoid doubting whether the amiable hospitality of the 'little people, exceeding wise' has not in it elements of danger. What if the guests became too numerous?

As a fine example of wheels within wheels, let us face this question and inquire what actually happens. The beetles are not unlike ants in their ways, and the larvæ of

Lomechusa, as described by Wasmann, are very like ant larvæ. At any rate, the ants make little distinction between the ant-larvæ and those of their guests ; they treat them both alike. Now it is the habit of the worker-ants to dig up the ant-larvæ and to clean them during the pupal metamorphosis ; and they do this likewise for their guests' larvæ. But while it is a good procedure for the ant-larvæ, it is disastrous to the beetle-larvæ ; the great majority perish under the treatment and perhaps only those which have been overlooked survive. Two naturalists at least have referred to this as an unfortunate circumstance, as an illustration of the well-known fact that ' the best-laid plans of mice and men gang aft agley ', but in reality the apparent failure is an unconscious success ; the result of the wheels-within-wheels complication is that the friends of the family do not become too embarrassingly numerous.

Karl Jordan has made an interesting study of the glands of *Lomechusa* and *Atemeles* and other related beetles which live as guests in ants' nests. Numerous unicellular glands on the sides of the abdomen produce the secretion that the ants lick with evident gusto. But there are also numerous offensive glands, common to other beetles of the same sub-family Aleocharinæ which are not myrmecophilous. The secretion of these offensive glands has an odour like that of amyl-acetate or methyl-heptenon, and it has, like these substances, a stupefying effect on the ants. It is used against stranger ants or against the hosts themselves when they are troublesome. The possession of the offensive glands gives the beetles a certain standing, so to speak, but it is on the possession of the palatable secretion that the myrmecophilous partnership depends.

CHAPTER II

THE HAUNTS OF LIFE

(The Exploitation of the Earth)

'She has divided herself that she may be her own delight. She causes an endless succession of new capacities for enjoyment to spring up, that her insatiable sympathy may be assuaged. . . .'

'She tosses her creatures out of nothingness, and tells them not whence they came, nor whither they go. It is their business to run, she knows the road. . . .'

—*Goethe's Aphorisms*, translated by Huxley.

The Shore Fauna—The Pelagic Fauna—The Abyssal Fauna—The Freshwater Fauna—The Terrestrial Fauna—The Aerial Fauna.

THERE are six great haunts of life: the shore of the sea, the open sea, the deep sea, the freshwater, the dry land, and the air. And these have their distinctive tenants. For while some types may be represented by very similar forms in more than one haunt, and while some animals pass from one haunt to another, yet on the whole there is distinctiveness in the faunas of the various regions. So we may speak of littoral, pelagic, abyssal, freshwater, terrestrial, and aerial faunas. Besides the great haunts there are minor haunts of much interest—such as caves, and brackish water, and underneath the ground. It must be granted, too, that parasitic animals have explored and

exploited a great variety of haunts in or on other creatures. In strictness, as we shall recognize later on, the freshwater haunt should be subdivided into several distinct haunts.

I. The Shore Fauna

We must think of the shore-area as much more than that stretch of sand and gravel and rock-pool and mud which many of us know so well—the happy hunting-ground of child and naturalist alike. The shore-area is much more than the stretch between tide-marks. It includes the whole of the shallow shelf around continents and continental islands, down to a depth of, say, 100 fathoms. It is the area where seaweeds grow. Geographers tell us that, without including the imperfectly known polar areas, the shore-area stretches for over 150,000 miles and has a superficial extent of perhaps nine million square miles. It is therefore an immense area, though it only occupies between 6 and 7 per cent. of the entire sea-surface. It makes up for its relative smallness by the density and variety of its population.

What strikes us first about the littoral area is that it is the meeting-place of the terrestrial, the freshwater, the pelagic, and the abyssal faunas. Over the marshy ground overflowed at high tides, or over the firm-turfed links, or abruptly up the cliffs, or tediously over the seemingly interminable sand-dunes, we pass from the littoral to the terrestrial. Up the long estuary there is often a gradual passage from salt water to fresh, and we notice some animals like flounders that don't seem to care which they live in. If we take a boat and sail out, or if we swim out in some places, we pass from the littoral to the pelagic area. If, on the other hand, we could walk down the gently

sloping shelf that often occurs, we should find the light becoming gradually fainter and the seaweeds becoming gradually scarcer, and if we could continue to a depth of about 100 fathoms, we should come to the 'mud-line' where wave-action ceases and the mud sinks quietly to rest. This is near the edge of the continental shelf, and beyond this is the steep slope leading down to the deep sea.

The shore-area has been divided by Forbes and others into zones: (*a*) the strictly Littoral or tidal zone, between the tide-marks, with limpets and acorn-shells, periwinkles and dog-whelks, cockles and mussels, sea-anemones and crumb-of-bread sponge; (*b*) the Laminarian zone, where the long pennon-like brown seaweeds grow in profusion with sea-urchins and starfishes and nudibranchs; and (*c*) the Coralline zone, with abundance of calcareous Algæ, and such animals as 'buckies' and 'sea-mice'. But shores differ so enormously that these zones are not of general occurrence; a great deal depends on the gradient, for the shelf may extend out for many miles, or there may be deep water up to the sides of the cliffs and no shore at all, as in the Scandinavian fjords. A noteworthy point that can be readily verified concerns the seaweeds. The dominant colour changes as we proceed outwards. Most of the green Algæ, such as the sea-lettuce (*Ulva lactuca*), are in the shallowest water; the brown ones, such as the huge Laminarians, are most predominant further out; the red Algæ, such as *Delesseria sanguinea*, are especially characteristic of the lowest zone of seaweeds. In the brown forms the chlorophyll is masked with a brown pigment (phycophæin), in the red forms with a red pigment (phycoerythrin), and the point of greatest interest is simply that

the red seaweeds are able to continue the work of assimilation in relatively faint light, though they do not form the ordinary kind of starch. It may be noted in passing that the pelagic Sargasso weed consists of pieces of littoral seaweeds (e.g. *Sargassum*) which have been torn by storms from the shore and floated outwards.

It is usually believed that the green Algæ came first historically, but it is interesting to notice Brunnthaler's heresy that the red ones are most primitive. His idea is that the red Algæ were physiologically best suited for the dim light of very ancient days when the Earth was enveloped in a dense cloud canopy, just as they are nowadays best suited for the deeper waters of the littoral area. Those with brown pigment came next and they were well suited to absorb rays from a somewhat lighter but still very misty atmosphere. The green Algæ came last in the series, when our present-day conditions were established. They proved very successful and spread from the sea to the estuaries and thence into the freshwaters.

Physical Conditions.—The character of the shore-fauna depends in part on the chemical composition of the water, which shows considerable diversity. This depends on the nature of the rocks and sea-bottom, on what the rivers bring down, and on what the currents sweep along. The nature of the rocks, whether volcanic or calcareous, granitic or sandstone, and so on, is also of much importance, determining, for instance, the nature of the rock-pools and the opportunities for attachment. On the nature of the rocks and sea-floor the vegetation of seaweeds in part depends, and the 'flora' reacts on the fauna.

It is part of the definition of the shore-area that it is illumined (hence its rich vegetation), but it is subject of

course to the vicissitudes of day and night (unknown in the Deep Sea) and of the seasons (there is eternal winter in the Deep Sea). The vicissitudes of temperature are much more marked than in the Open Sea. With its tides and storms and floods, the shore-area is on the whole very difficult and 'trying'. Its tenants must be familiar with what has been called 'the discipline of dislodgment'. We may refer to the wreckage of life seen in the jetsam after a heavy storm, to the effects of a very hard winter on the shore population the following summer, and to the long-lasting effects of the last eruption of Vesuvius on the fine littoral fauna of the Bay of Naples.

There are, it is true, circumstances in which the life of the shore is sheltered from much of the mercilessness of the physical forces—we are thinking of the deep holes whose sides are unscoured except by the severest storms, the sunny shallows on the inner side of the breakwater formed by a barrier coral-reef, the stretches of lagoon protected by a mangrove belt a mile broad, and the great mud-line itself where wave-action has ceased. These are instances of conditions where delicate organisms may live a sheltered life even within the littoral area, but in most cases the reverse is much nearer the truth. The shore is a hard school where lessons are driven home with blows and where risks are continuous. It furnishes many illustrations confirming Tennyson's conclusion in regard to one aspect of organic Nature:

> That life is not as idle ore
> But iron dug from central gloom
> And heated hot with burning fears
> And dipped in baths of hissing tears
> And battered by the shocks of doom
> To shape and use.

A Representative Fauna.—The shore-fauna is certainly the most representative of all faunas. What pictures rise in the mind! Swiftly moving Infusorians lashing their way through the water; Foraminifera with beautiful shells of lime slowly gliding on the fronds of seaweed; calcareous sponges like little vases and more irregular flinty-and-horny sponges, sometimes coating the rocks like the common crumb-of-bread sponge, sometimes growing in beds like the plants they were once supposed to be; hydroid zoophytes like miniature trees on rock or seaweed; sea-anemones and corals often like beds of flowers, living an easy-going life, waiting for food to drop into their mouths, or stinging small passers-by; unsegmented worms such as the 'living films' which glide on the seaweeds or stones like mysteriously moving leaves, and the Nemertines or ribbon-worms, also covered with cilia, but provided with a remarkable protrusible proboscis, sometimes ejected so violently as a weapon that it breaks off altogether and wriggles like a worm itself; the higher ringed worms or Annelids in extraordinary numbers, like Nereis, Phyllodoce, and Aphrodite itself, so beautiful in themselves and in their names that we can understand the enthusiasm of the expert who is said to have named his seven daughters after seven favourite Polychæts; the starfish creeping up the rocks with their strange hydraulic locomotor system, the brittle-stars using their lithe arms like gymnasts, the sea-urchins tumbling along on the tips of their teeth, and the sluggish sea-cucumbers plunging their tentacles into the mud and then into their mouths; the beautiful colonies of 'Moss-animals' or Bryozoa, crusting stone and weed as if with lace, or forming leaf-like fronds like the sea-mat (Flustra), which was one of the

first animals Charles Darwin worked at, or growing into calcareous tufts as if in mimicry of corals; myriads of Crustaceans, such as water-fleas, acorn-shells, beach-fleas, sandhoppers, no-body crabs, sea-slaters, shrimps, hermit-crabs, and shore-crabs proper; strange sea-spiders, neither crustaceans nor spiders, like *Pycnogonum littorale*, clambering among the seaweeds and hydroids; an occasional insect and even myriopod about high tide mark; spiders in the caves and among the dry rocks; bivalves innumerable, such as cockles and mussels, oysters and razor-fish; herbivorous gasteropods like periwinkles, and voracious carnivores like the dog-whelks and buckies; sedentary limpets with a slight range of movement and a slight memory for locality, since beyond a narrow radius they fail to find their way home; an occasional cuttle-fish caught in a shore-pool and many more further out; a large representation of ascidians or sea-squirts, both simple and compound, which lie at the base of the Vertebrate series; the lancelets (Amphioxus) buried all but their mouth in the fine sand; true shore-fishes like sand-eels and gunnels and shannies; an occasional reptile like the lizard Amblyrhynchus which swims out among the rocks, or a poisonous sea-snake, or a turtle coming ashore to lay her eggs; numerous shore-birds like oyster-catcher and rock pipit, gull and cormorant; and an occasional mammal like otter and seal—on the whole *a more representative fauna than in any other life-area.*

We must not, of course, include among the shore animals strayed pelagic forms, such as jellyfishes, which are often stranded in enormous numbers. Millions of inwafted "Night-Light" Infusorians, Noctiluca, sometimes form a reddish brown ridge on the beach, but one might as well

include a stranded whale in the littoral fauna. As we shall see later on, many of the distinctive littoral animals pass through a pelagic phase, but that again is a different matter. Our point at present is the simple one, that there is much in the jetsam which does not belong to the shore.

Keen Struggle for Existence.—It is evident that the shore-area must be characterized by a keen struggle for existence. In the open sea there is practically no limit to the floating room and swimming room, but the shore is narrow and crowded. In a rock pool there is often no vacant niche. There is competition even for *foothold.* It is important for instance that the limpet which makes little journeys in search of seaweed to nibble should not go too far, else it will not find its way back, and will have lost the spot which its shell has grown to fit. It is curious, too, to see the American slipper-limpet—one growing on the top of another to the number of four or five—suggestive of the root-idea of a sky-scraper.

There is abundant food in the shore-area, for there is a great crop of seaweeds to start with, but there is nothing to compare with the pelagic sea-meadows—an inexhaustible supply of microscopic Algæ extending for square mile after square mile, and for many feet in depth. Thus on the shore there is much more struggle for *food*—competition around the platter. It is lessened by the fact that there is considerable variety in the dietary, some being carnivorous, others vegetarian, others feeding on microscopic animals, and others on debris, but one must remember that even the crumbs of organic matter, formed on the shore or brought down by rivers, are always being swept away by the undercurrent to greater depths. The most must be made of them before they are lost.

We often see 'nutritive chains'—the worm feeding on debris, the crab feeding on the worm, the shore-fish swallowing the crab, the herring gull with a swoop lifting the fish from near the surface of the water, the skua gull chivying the herring gull and forcing it to relinquish its booty. There are hundreds of similar concatenations.

There is struggle for foothold, struggle for food, and struggle against dislodgment; and it takes every form from a literal struggle for subsistence to a competition for luxuries, from a life and death combat to a rivalry of wits. The oyster-catcher tries to knock the limpet off the rock with a dexterous stroke of its strong bill, the limpet tries to hold fast; the carnivorous sea-slug—sometimes secreting dilute sulphuric acid from its mouth—tries to bore through the back of a starfish which may succeed in dislodging its enemy by creeping under a low shelf of rock; the hermit-crab seizes a worm, the worm breaks into two, and the hermit-crab falls in among the tentacles of a large sea-anemone. In a thousand forms there is that reacting against difficulties and limitations which is the essence of the struggle for existence.

In illustration of weapons in more detail, let us take the case of the sea-urchin. Among the large spines on its test there are minute ones (pedicellariæ) with three snapping blades. They suggest three-bladed shears on the end of a long flexible stalk. Some of them help to grapple food-particles, some keep the test clean, and others, as Prouho and von Uexküll showed, give poisonous bites. On the dorsal surface of the beautiful golden-yellow heart-urchin, *Echinocardium flavescens*, there are many of these poisonous 'gemmiform pedicellariæ' which have been observed to work very effectively. Gandolfi Hornyold put a small

Annelid worm on the back of the heart-urchin and watched the spines snap at it. A reddish fluid flowed out from their tips and the worm was dead after a few minutes of violent wriggling. The minute pedicellariæ then separated themselves off from the test and remained imbedded in the worm. They all broke at the same place, just at the joint between the base of the spine and the test, and some of them were re-grown in about a month. The re-growth of these weapons is interesting, and it may be recalled that the common sea-urchin (Echinus) has also the power of regenerating its spines and these only. Because of the globular nature of its body it is not exposed to the risk of losing parts, and we can thus understand why it does not exhibit autotomy and re-growth on the scale illustrated by the starfish and the brittle-star.

In connexion with the pedicellariæ, it is interesting to notice that a starfish will get the better of a small sea-urchin by applying first one and then another of its arms, to the spiny surface, getting it well nipped by pedicellariæ, and then wrenching off a whole crowd. It does this persistently over and over again until the sea-urchin is robbed of all its weapons.

As an illustration of armour the sea-urchin might also serve, but let us turn to Molluscs. Every one who knows the molluscs of the shore, or has enjoyed a ' beauty-feast ' looking over the cases of shells in a museum, must have been struck with the solidity of many of these encasements and with the frequently elaborate outgrowths from the surface—knobs, shelves, roughnesses, peaks, undulations, and what not. There is a suggestion of sheer exuberance about many of them, and it looks as if there were a waste of shell-making material and energy. The explanation is

probably in part physiological—though as yet beyond statement—for instance that the deposition of conchin and carbonate of lime by the skin or mantle may be an organized way of dealing with the waste products of the animal's body, and perhaps also with by-products of digestion.

This must remain vague in the meantime, and therefore we turn with pleasure to a secondary or œcological explanation which has been suggested by Mr. Cyril Crossland—that the thickness of the shell and the outgrowths on it must be credited with protective value. The shell-eating fish Balistes prefers the bivalves with weaker shells. Another enemy, the boring gastropod Murex, kills more of those with smoother shells. It kills large numbers of *Margaritifera mauritii*, which has small and weak outgrowths on its shell; it kills few of another species, *Margaritifera margaritifera*, which has large strong processes remaining for at least six years. It seems that the strong processes on the surface of the shell prevent the Murex from readily getting a firm hold with its foot, and without this it cannot work the drill in its mouth that it uses to bore through the bivalve's defences. In some species of bivalve the outgrowths of the shell are larger in the young forms, and they are of the greater value therefore during the relatively more active period when the young pearl oyster, or hammer-shell (Avicula), or Tridacna, is crawling about and seeking a suitable place for settling down on. Mr. Crossland's suggestion may require modification, but he backs it up with definite facts showing the actual life-saving value not of the armour merely, but also of the decorations which it bears.

When the Murex gets a good grip on a relatively smooth shell it drills a hole through, and allows some paralysing

mucus to enter; but there is a quicker method. 'It finds the flexible edge of the shell, then by contractions of its foot breaks a piece away. The mucus of the foot is then poured out in quantities, and this has some poisonous effect, as the bivalve, while still untouched, ceases to respond to the stimuli which ordinarily cause a smart closure of the shell'. If the shell is covered with rough decoration the Murex finds the burglary more difficult.

Infantile Mortality.—The shore is a 'congested district'; the birth-rate is high; the infantile mortality is enormous. Under the ledges of the rocks and in the crevices we find in abundance the neat little vase-like cases, we may almost say cocoons, which the dog-whelk (*Purpura lapillus*) forms for its eggs. They change from a light pink to a straw colour. Each is the scene of a tragedy. If we examine a freshly formed vase we find that it contains scores of eggs. Later on, we find only about half a dozen embryos. What has become of the majority? Careful examination at intervals shows that some of the eggs get the start of others in their development, and that the leaders devour the laggards, and continue to lead because they do so. The same is true in the egg-capsules of the great whelk or 'Buckie' (*Buccinum undatum*)—cases reminding one of the fruits of hops, cemented together into balls often the size of an orange, or much larger. Inside each capsule there is the same grim elimination—the survivors use their fellows as other embryos use the yolk of the egg. There is no lack of brutal frankness in some of Nature's ways, 'so careful

FIG. 20.—Three egg-vases or capsules of the Dog-whelk, *Purpura lapillus*, fastened to the rock.

of the type she seems, so careless of the single life'; for here we have cannibalism in the cradle, the struggle for existence at the very threshold of life.

In the pool where we gathered the Purpura capsules, we may see the beautiful Tubularians, e.g. *Tubularia indivisa*, waving their tentacles, and it is interesting to remember that in the ovary of Tubularia, as in that of the freshwater Hydra, there is a struggle for existence among the numerous possible eggs. A few survive in Tubularia, one survives in Hydra; it is a case of engulfing the other ova. Thus we see how wide the conception of the struggle for existence really is—that it applies even to the germ-cells; and our thoughts pass on to Weismann's daring speculation that there may be a struggle between the ancestral contributions which make up the inheritance within the egg.

Speaking of 'infantile mortality' leads us naturally to think of the various ways in which it is lessened. These show an interesting parallelism with rational methods in operation in mankind. The first method is to transport the delicate young lives from the rough-and-tumble life of the seashore to the open water. Starfishes, sea-urchins, and their allies, many worms of diverse kinds, many crustaceans and molluscs have delicate larvæ, altogether unsuited to stand the hard conditions of the shore, but admirably suited for a period of pelagic swimming or drifting. It is true enough that Death often finds them there also, but they are certainly much safer than near the shore.

It is an interesting question whether the pelagic habit of the larvæ of some shore animals is an indication that the cradle of the stock to which they belong was the open sea, just as the littoral habit of the robber-crab's young is an indication of the original shore home of this terrestrial

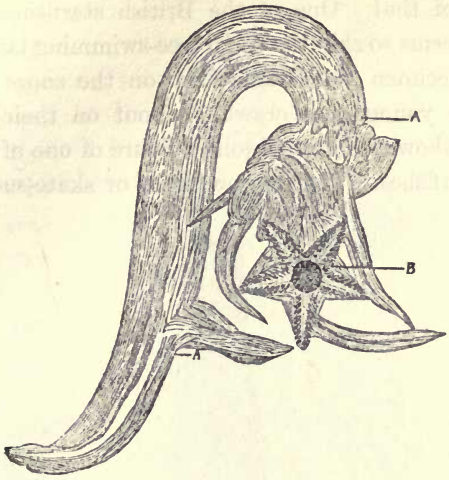


FIG. 21.—Free-swimming pelagic larval starfish—the Bipinnaria of Luidia—enormously enlarged, showing transparent larval body (A) with curious processes, and the young starfish (B) being formed. (*After* McIntosh.)

animal. Or is it a quite secondary new departure on the part of what one may call autochthonous shore animals, this getting their young into a relatively safer area? Is it similar to the case of the aquatic habit of the larvæ of many insects, such as gnats and mayflies, which is believed to be quite secondary? There is most to be said for the view that the pelagic phase of some shore-animals is secondary. The larvæ are often highly specialized in relation to open-sea life, and not the least like ancestral forms. In certain cases the first view may be entertained.

Parental Care.—Returning to the avoidance of infantile mortality, another method of life-saving is to increase parental care and nurture; and the shore is rich in illus-

trations of that. One of the British starfishes, *Asterias mülleri*, seems to skip the usual free-swimming larval stage, for a specimen has been seen on the shore with the miniature young ones crawling about on their mother's body, as shown in the subjoined figure of one of the *Challenger* starfishes. The marine leech, or skate-sucker, lays

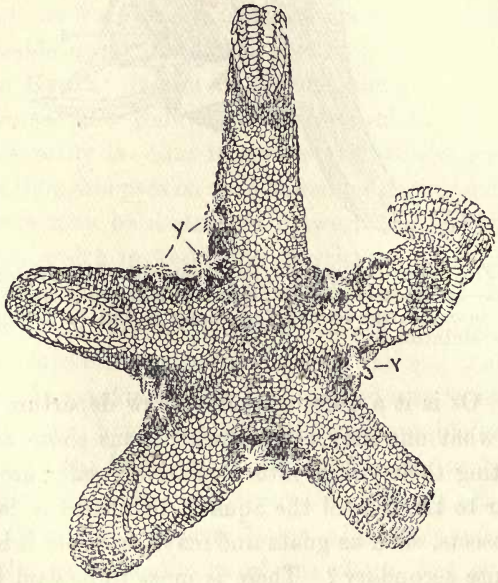


FIG. 22.—A starfish, *Leptoptychaster kerguelensis*, with the young ones (Y), clambering about on the mother, the free-swimming larval stage having been suppressed. (*After* the *Challenger* Report.)

its eggs in the empty shell of a bivalve mollusc, and mounts guard over them week after week, carefully removing any mud or debris that might smother them. In a number of shore crustaceans the young are carried about by the mother, and may move about on her body in a very quaint

way, now hanging on to her antennæ and again to her tail. It is the male sea-spider or Pycnogod that gets hold of the eggs and carries them about attached to a pair of appendages, and it is likewise the male sea-horse (Hippocampus) who stows away the eggs in a capacious breast pocket and carries them there till they are hatched.

We cannot exhaust our admiration for the male

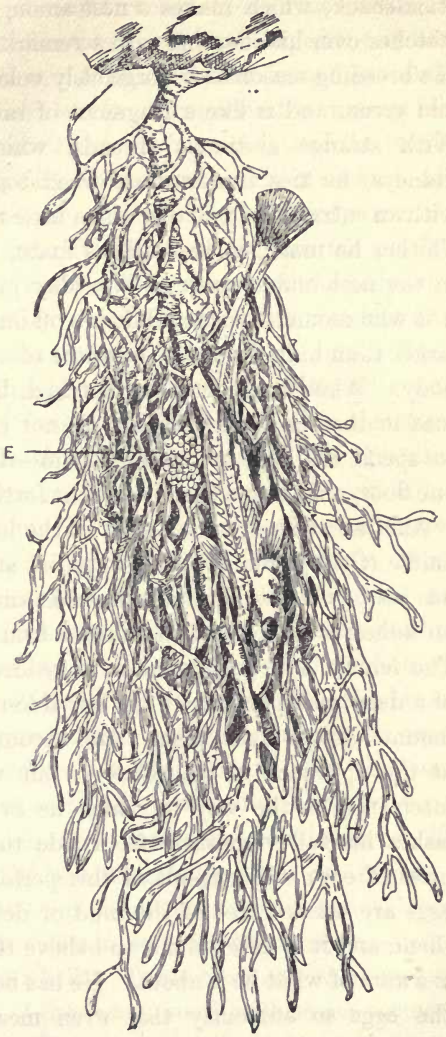


FIG. 23.—Nest of the fifteen-spined Stickleback, Gasterosteus spinachia, among the seaweed. E. A bunch of eggs. (From a specimen.)

stickleback, which makes a nest among the seaweeds, and watches over his offspring with a remarkable devotion. At the breeding season he is gorgeously coloured in red, orange and green, and is like a fragment of rainbow in the pool. With strange glutinous threads, which come from his kidneys, he ties fronds of seaweed together into a nest with an entrance and an exit and a little room in the middle. Thither he manages to lead his mate, who lays her eggs in the nest and returns to everyday pursuits. The male it is who mounts guard and drives off intruders, often much larger than himself—a fine example of a big soul in a little body. When the young are hatched, like animated commas in the water, his labours do not cease, for he seems to spend his day in tending them—driving them in at one door, only to see them reappear forthwith by the other.

Another striking case is that of the lumpsucker or cockpaidle (*Cyclopterus lumpus*), a quaint sea-shore fish which has its pelvic fins shunted forwards and transformed into an adhesive sucker which takes a firm grip of the rocks. The female lays a large mass of reddish eggs in a recess of a deep rock-pool about the low tide-mark, and the male mounts guard over them. He becomes greatly excited at the approach of an intruder, but what is even more interesting is the way in which he every now and then lashes his tail vigorously from side to side close by the mass of eggs. The result of this performance is that the eggs are washed free of the mud or debris that settles on them, and it is difficult not to believe that the lumpsucker is aware of what he is about. He has been known to guard the eggs so anxiously that even meals were neglected.

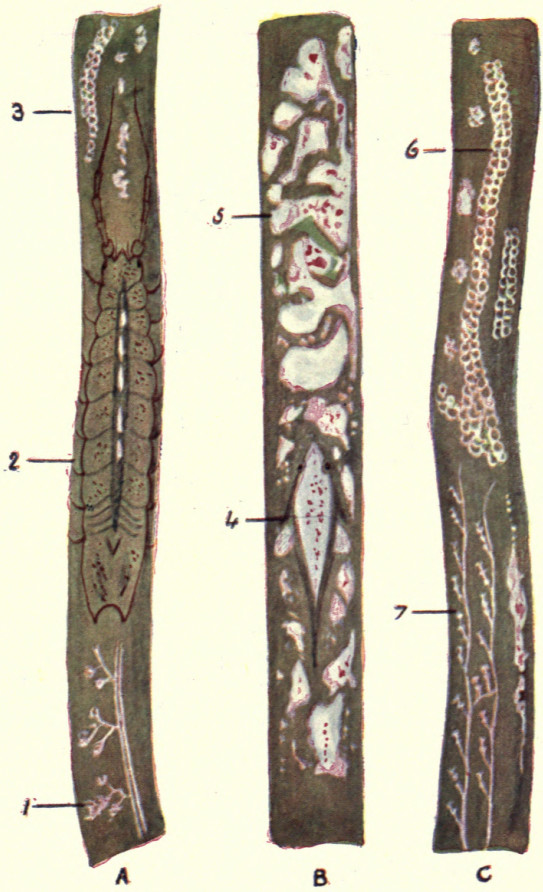
The infantile mortality may be lessened, as we have seen, by a migration to open water, or by an increase of

nurture. It may be counteracted, though not lessened, by enormous multiplication; and that expedient is also familiar on the shore. A single oyster may have sixty million eggs—which leaves a considerable margin for deaths. We may recall also the famous case of the palolo-worms (*Eunice viridis*) of the coral-reefs of Samoa and elsewhere. Once a year, with striking regularity, myriads of these worms crawl out tail foremost from the crevices they inhabit, and agitate themselves so violently that while the head end remains in the rock the posterior ends drop off and make the water ' like vermicelli soup'. These headless worm-bodies are laden with egg-cells and sperm-cells, and these are shed in countless millions in the water, so that the fertilization is quite secure. The swarming begins shortly before sunrise, and it is mostly over in half an hour. Everything is extraordinary—the sharp punctuation of the time of reproduction (different in Pacific and Atlantic), the subtle stimulus of the moonlight and the sunrise, the discharge of the multitudinous writhing bodies, the profuse sowing of the seed; but perhaps the most extraordinary thing is the evasion of the death-penalty which reproduction, especially exuberant reproduction, often involves for the parent. For the heads remain in the reefs and grow new bodies at their leisure.

Given stimulating and hazardous conditions of life, and keen competition among organisms, we expect to find special adaptations, and the shore is full of them. We have already referred to effective armour, such as we see in crab and whelk. These have also their weapons and so have many of the unarmoured, such as sea-anemones and ribbon-worms (Nemerteans). Starfishes and brittle-stars and many others illustrate the adaptation of ' auto-

tomy' or self-mutilation, losing a member or part, but saving the whole life, and able at leisure to regrow what they have lost. Protective colour-resemblance is frequent, as we may see in young shore-crabs (*Carcinus mœnas*) which show many different colours and patterns, and are often most effectively like the substratum of the rock-pool on which they rest. We shall discuss later on the extraordinary power of protective colour-change in some prawns (*Hippolyte varians*), and that of young flat-fishes, as they assimilate themselves to the sand or gravel, is not less perfect, though within a narrower radius. The sand-crab (*Hyas araneus*) and others mask their carapace with seaweed, so that they move about under an innocent disguise, anticipating on their own line such human tricks as 'the walking wood of Birnam'. And this is only the beginning of a list of life-saving adaptations in the shore-area.

We cannot pass from this brief study of the littoral fauna without recalling the probability that it was on the sea-shore that many of the most valuable of vital acquisitions were made. Many of the great types of animal life have been to school on the shore, and who shall say what lessons they did not learn amid that rough-and-tumble life, where changes come often, where competition is keen, where the discipline of dislodgment is ever recurrent, where a premium is put on alertness and persistence and adaptability? The shore has been a great school of life. Yet in saying this we do not wish to imply that the wisdom of any animal race whatsoever has been due to the premiums which individuals have paid to experience. For this theory of entailment does not seem to us to describe Nature's method.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Peculiar Conditions.—There are many peculiar haunts of life which must be regarded as subdivisions of the main haunts, though they have come to have very little in common with any one of them. Thus we find a peculiar set of animals in the salt marshes which occur here and there along the coasts; in continental salt lakes which have no connexion with any present sea; in hot springs where animals may sometimes be found flourishing at a temperature of 45°C.

II. The Pelagic Fauna

The conditions of life for open-sea or pelagic animals must be regarded as on the whole very favourable. For there is plenty of room and there are no boundaries to be dashed against till a shore is reached. A storm can be avoided by sinking for several fathoms. There is sunshine without any risk of drought, and more uniformity throughout the day and throughout the year than is to be found elsewhere except in the monotonous abysses of the deep sea. The extraordinary abundance of microscopic Algæ at the surface and down for many fathoms ensures an inexhaustible food supply for the animals. There is unlimited 'sea-soup'. It is not surprising, therefore, to find that the open sea has been peopled from the earliest times of which the fossil-bearing rocks give us any record.

Dr. J. Y. Buchanan, who has given much attention to the study of the colour of the sea, points out that a deep olive-green, common in polar latitudes, but not confined to them, is due to an abundance of diatoms and to the excretions of animals that live on diatoms. From the polar ice to beyond the fortieth parallel, the surface

water is a pronounced indigo colour. From the equator to beyond the thirtieth parallel, the colour of the surface water is a pure and brilliant ultramarine. The olive-green, the indigo and the ultramarine are the three great colour-types of the sea.

Open Sea.—One must be careful to notice that pelagic does not mean at the surface; it means 'open sea' and as far down as clear light reaches. Many small organisms have their maximum at a depth of 50 fathoms below the surface, and a great advantage of being several fathoms down is that a measure of calm is enjoyed. Dr. A. G. Mayer brings this out very vividly in his memoir on the Ctenophores or 'sea-gooseberries' of the Atlantic coasts of North America—fascinatingly beautiful animals of the Cœlenterate series, distantly related to Medusoids.

'In the extreme tenuity of their bodily substance and their diaphanous delicacy of coloration, the ctenophores stand apart from other marine animals. Their presence in the water is commonly denoted only by the brilliant flash of rainbow colours, which play along the lines of their ciliary combs as they move languidly beneath the unrippled surface of the sea. Yet these creatures are no more wonderful in their complex organization than in their remarkable adjustment to their habitat: for so delicate are most of them that a current such as that of an oar suffices to tear them into misshapen shreds—a fate which they escape in time of storm by sinking far into the depths. This fact accounts for the extreme rarity of many of these forms, for the ocean's surface must have remained flat as a mirror for many hours before they can be lured upward from the calm of their deep retreat.'

We must distinguish between the surface plankton

and the sub-surface plankton, both within the light-limit, and the bathy-plankton which extends below that limit, and consists necessarily of animals only.

Swimmers and Drifters.—The open-water animals (Plankton, in the wide sense) are conveniently divided into the active swimmers, such as fishes, which make up the Nekton, and the more passive drifters, with relatively feeble organs of locomotion or none at all, that are swept about at the mercy of tides and currents. Another general distinction should be borne in mind,—that between the permanent and the temporary planktonic animals, for while there are many creatures that spend their whole existence in the open sea, such as Ctenophores and Portuguese Men of War, there are others, which are only there as larvæ, e.g. the swimming bells of littoral zoophytes, and the young stages of many worms, echinoderms and molluscs.

Representative Pelagic Animals.—The pelagic fauna is made up of a great variety of types, from the pin-head-like Noctiluca, whose intense luminescence sets the waves aflame in the short summer darkness, to the great whales —the giants of the present age. The list includes many Foraminifera (especially the Globigerinids), thousands of different kinds of Radiolarians (so successful perhaps because they have partner Algæ living inside them), the active Dinoflagellates (much sought after by small crustaceans and even by fishes), many other Infusorians, jelly fishes or Medusæ, often in great fleets, and the swimming-bells or Medusoids, many of which are the liberated reproductive buds of sedentary zoophytes, strange colonies known as Siphonophores such as the Portuguese Man of War and Velella, the delicate Ctenophores which never come to the surface unless it is very calm, not a few free-

swimming 'worms', such as Sagitta—like a glass arrow in the water, a few Holothurians or sea-cucumbers which have departed widely from the prevalent habit of their class, a legion of Crustaceans often of surpassing beauty of colour and form, a few insects (Halobatidæ) the last creatures one would expect, such molluscs as the sea-butterflies (Pteropods)—dainties which the whalebone whale captures in countless myriads in the great sieve which hangs down from the yawning cavern of its mouth, the similarly light-shelled or shell-less Heteropods and many actively swimming cuttlefishes, such as the Argonaut, some Tunicates like the Salps (often swimming gently in long transparent chains) and the 'fire-flame' (Pyrosoma) famous for its luminescence, numerous fishes such as flying fishes, a few turtles and venomous sea-snakes, such birds as Mother Carey's Chickens and the flightless penguins, and among mammals the cetaceans large and small. This abbreviated roll may serve to suggest the representative character of the pelagic fauna. Within the pelagic fauna it seems right to include the petrels, since they are distinctively ocean-wanderers, and very seldom come ashore except for breeding. An ancient race, marked by their protruding tubular nostrils and their compound bill of

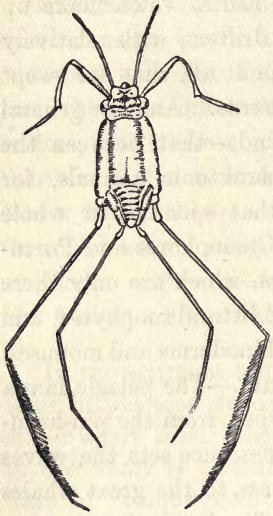


Fig. 25.—Halobates, a pelagic insect, one of the Hemiptera. (*After* Buchanan White.)

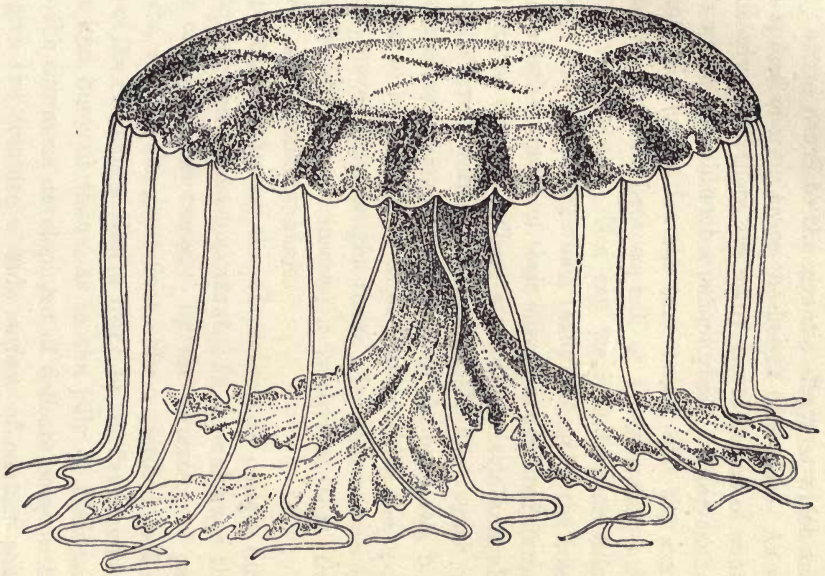


FIG. 26.—Jellyfish, or Medusa, Dactylometra quinquecirra, side view. (*After* Agassiz and Mayer.) This medusa is usually accompanied by small fishes.

several horny plates separated by deep grooves, the petrels appear to have been very successful, for they are to be found in all the oceans—including the Arctic and Antarctic—and they are represented by a great variety of types from the tiny storm petrel to the gigantic albatross which may have a spread of wing twice the height of a man. As we have already said, there are many larval forms of shore animals which pass through a pelagic phase. They cannot be counted in except for the time being, and the same must be said of the Leptocephali or transparent young stages of various eels. Nor can we include such fishes as salmon and sea-trout, which really belong to the fresh waters, though so much of their energy is acquired during their visits to the sea. There are some pelagic animals, such as the arrow-worms (Sagitta and the like), which we can think of as having always lived in the open sea, but most seem to bear the impress of lessons which the open sea could never have taught them. In such a case as the Halobatidæ (pelagic insects) it is obvious that the open sea is a secondary home.

Adaptations.—Among the adaptations to pelagic life, the following seem most important. In several ways the floating capacity is increased: by the formation of gas reservoirs, such as the great float—like a glorified cock's-comb—of the Portuguese Man of War; by the development of light and buoyant tissue, as in the jelly of Medusæ; and by the enormous development of delicate outgrowths which give the creature a wide surface of contact with the water, as we see, for instance, in many of the pelagic Crustaceans. We cannot glance at them without feeling that architecture of this sort could not survive the sea-shore conditions for a day.

Many open-sea animals are transparent; many of those that live near the surface have beautiful blue and violet colours, well seen in the Siphonophore Velella and in the Gasteropod Ianthina. It is possible that there is occasionally some adaptiveness in the transparency, though this quality follows for the most part from the lightness of build. It must in some cases make the swimmers or drifters practically invisible. Even in a small bowl of sea-water it is very difficult to see an arrow-worm (Sagitta) or the like, and it is very interesting to watch in a large aquarium how the quite unique Venus's girdle (*Cestus veneris*), which is at once transparent and iridescent, is conspicuous at one moment—a creature of positively dazzling beauty—and invisible the next. Some pelagic fishes, such as a quaint little sea-horse, which live among the Sargasso weed, have the body reddish brown, but the fins, which are spread out in the open water, are a beautiful transparent blue. It is no argument against the theory that transparency is advantageous to point out that it is often of no avail, e.g. when the great Cetacean catches thousands of sea-butterflies in its net.

There is evidently a considerable intensity of life in some of the Plankton animals, for their movements are practically ceaseless, and their sensory equipment, especially in the way of eyes and balancing organs, is often very remarkable. Many are 'phosphorescent', such as Noctiluca, Ctenophores, Pyrosoma, but the vital significance of this remains a riddle. Many move about in shoals, which indicate prolific reproduction and great abundance of food. The numbers are greatest in the colder seas, which is probably due to the fact that at low temperatures growth and development are slowed, the life is drawn out,

and more generations are living at the same time. In some cases the large number of different species, within a relatively narrow radius, is very characteristic. Thus there are over 5,000 species of Radiolarians. This, perhaps, means that the conditions of life are relatively easy and Natural Selection not very stringent.

There is much still to learn in regard to the vital economy of the sea, for instance as to the food supply. It has been calculated by Pütter and Dakin that the 'producers' (the plant-plankton) are often insufficient for the 'consumers' (the animal plankton), and Dr. Dakin has also maintained that, even if there were enough of food, it would be 'an altogether unthinkable piece of work' for the animal to catch enough to cover its physiological expenditure. Dr. Dakin calculates that a sponge sixty grammes in weight would require to filter several thousand times its own volume of water per hour in order to obtain sufficient food, which sounds a somewhat formidable task. A big jellyfish, he calculates, would require over seven millions of nauplius larvæ per day, which is literally a large order. 'It is quite impossible for such large quantities to be caught, and equally strange that remains of the creatures are so rarely found, if they have been captured as food'. Perhaps it is too soon, however, to be very confident in regard to the amount of organic material that a creature like a sponge or jellyfish requires to cover the loss due to its metabolism.

Prof. Pütter's view is that many marine animals are in a way saprophytic—feeding on the organic compounds contained in solution in the water. He regards the sea as a great reservoir of dissolved foodstuffs (compounds of carbon other than carbonates, and compounds of nitrogen

other than ammonia, nitrates and nitrites). The question is, how much of this foodstuff there really is; and here the doctors differ. It is quite possible that organs with a large surface, notably gills, have a directly nutritive value. Prof. Pütter's strongest argument is simply that the solid food-supplies taken in by various types—e.g. sponge and crustacean—are not sufficient to account for the chemical changes that are known to go on. But the comparative physiology of marine invertebrates is still very young. In any case we must not too hurriedly dismiss the idea that there may be, especially in crowded zones, a sort of permanent 'stock' to the sea-soup. Every one who has examined, even with the fingers, the foam that is blown ashore from a rich littoral region after a storm, will agree that there may be much dissolved organic matter in the water. But this is no matter for opinion. It remains to be seen, by careful analysis and *after elimination of all the plankton*, how far it is true that there is bread in the waters.

Recent investigations at Port Erin Biological Station, by Prof. Benjamin Moore and others, have not in the least confirmed Pütter's view. Of great importance beyond doubt in the economy of the sea are the extremely minute organisms of the 'dwarf plankton,' so small that they pass through the interstices of fine silk cloth (see Fig. 34).

There are very interesting seasonal variations in the amount of the Plankton, the two maxima being in spring and autumn. Waves of abundance follow one another in a regular order; thus there is usually to begin with a great multiplication of Diatoms, then of Dinoflagellata, and then of Copepods. The reasons for the seasonal variations are still being investigated, but there is indication

that the spring exuberance depends largely on the sunlight, and partly on the temperature of the water and vertical currents in the sea which aid in the circulation of food materials.

III. The Abyssal Fauna

Every one has seen more or less of the other haunts of life, but no one has had any vision of the Deep Sea—the abyssal region beyond the light limit and the plant limit. Many have been within a stone's throw, or drop rather, of it; a few have had the rare experience of dredging from its distant floor; many have examined Deep-Sea animals in museums; but no one has ever seen its secrets in their natural setting.

The study of the Deep Sea is relatively modern, but its progress has been strikingly rapid. In 1818 Sir John Ross dredged a brittle-star (*Astrophyton*) from 800–1,000 fathoms, but this discovery appears to have supplied no stimulus. In 1841 Edward Forbes dredged without result in deep water in the Mediterranean, and Sir James Ross's similar attempts in 1847 were not more successful. Naturalists of the middle of the nineteenth century spoke of the Deep Sea as an abyss where life is either extinct, or exhibits but a few sparks to mark its lingering presence. In 1860, however, when the cable from Sardinia to Algiers was lifted for repair from a depth of 1,000 fathoms, fifteen animals were found attached to it—a discovery which fired enthusiasm. Surgeon-General Wallich should be remembered, we think, as one of the early pioneers, along with W. B. Carpenter, Huxley and Wyville Thomson. The cruises of the *Lightning* (1868) and the *Porcupine* (1870)

showed that most of the invertebrate types were represented at depths of 600 fathoms or more. These preliminary samplings led on to the famous voyage of the *Challenger* (1872–76), which, like Darwin's voyage on the *Beagle*, may be ranked as a Columbus voyage in the history of biology. Darwin's voyage led to the discovery of a new world—for the evolution idea made everything new; the *Challenger* voyage led practically to the discovery of the new world of the Deep Sea. Under Wyville Thomson's leadership the explorers cruised for three and a half years over the wide oceans, crossing the Atlantic five times, covering 68,900 nautical miles, reaching down with the long arm of the dredge to depths equal to reversed Himalayas, raising treasures of animal life from over five hundred stations, and bringing home spoils which have taken forty huge volumes to describe. The results, under Sir John Murray's editorship, have supplied a broad foundation for the science of oceanography, and given a powerful and lasting impulse to zoology in general.

Without dwelling on historical facts, we venture to call attention to three points. (1) It was out of a practical task that the stimulus to Deep-Sea exploration arose, and there has been on the part of science some repayment of this debt. (2) What happened is a warning against dogmatism. It is not very long since an authority spoke of the floor of the Deep Sea as 'an area regarding which nothing was known, nor could be known'; and now there is a large library of descriptive reports. (3) What the *Challenger* began has been followed up by expeditions from most of the countries of Europe and by the magnificent work of the late Professor Alexander Agassiz in America.

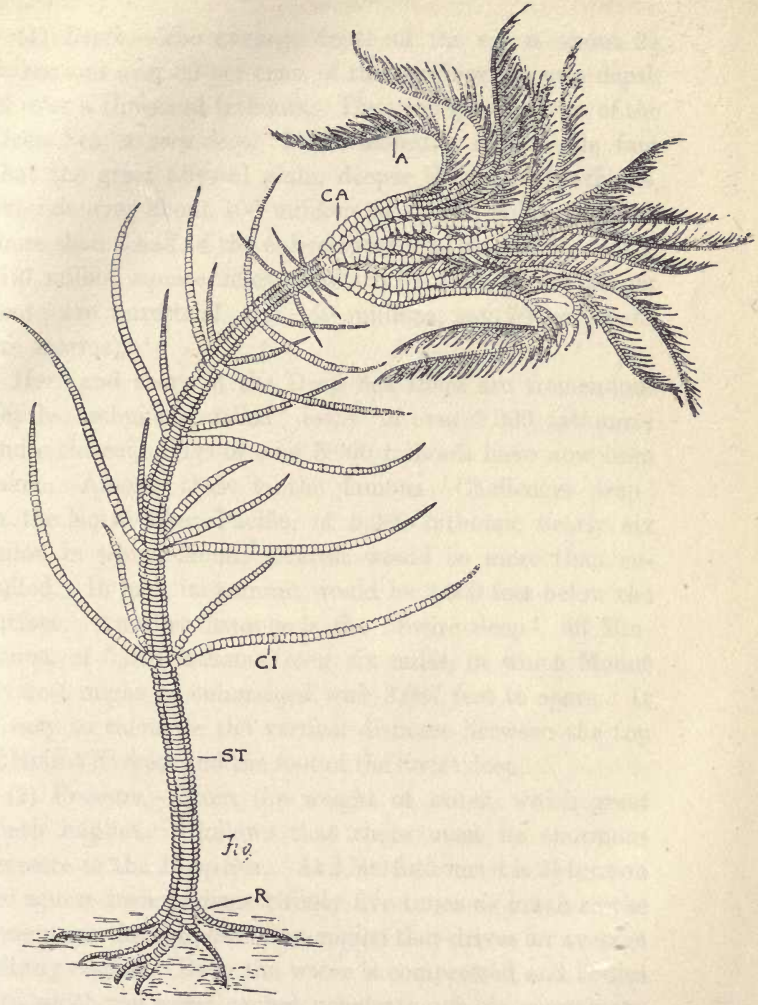


FIG. 27.—Deep-sea Crinoid (Metacrinus), showing the attaching 'roots' (R), the stalk (ST) giving off 'cirri' (CI), and the calyx (CA) with ten feathered arms (A).

Physical Conditions

(1) *Depth.*—The average depth of the sea is about 2½ miles, and over 80 per cent. of the sea-floor lies at a depth of over a thousand fathoms. Thus the greater part of the Deep Sea is *very deep.* It is, indeed, a remarkable fact that the great abyssal plain, deeper than 1,700 fathoms, extends over about 100 millions of square miles, which is more than a half of the entire superficial area of the earth (197 million square miles, of which 57 millions, say 30 per cent., are terrestrial, and 140 millions, say 70 per cent., are marine).

Here and there in the Deep Sea there are tremendous depths, technically called 'deeps', of over 3,000 fathoms; and eight soundings of over 5,000 fathoms have now been taken. Among these is the famous 'Challenger deep' in the North-West Pacific, of 5,269 fathoms, nearly six miles, in which Mount Everest would be more than engulfed. In fact, its summit would be 2,600 feet below the surface. Another instance is the 'Swire deep', off Mindanoa, of 5,348 fathoms, over six miles, in which Mount Everest might be submerged with 3,087 feet to spare. It is easy to calculate the vertical distance between the top of Mount Everest and the foot of the Swire deep.

(2) *Pressure.*—From the weight of water, which great depth implies, it follows that there must be enormous pressure in the Deep Sea. At 2,500 fathoms it is 2½ tons on the square inch, perhaps twenty-five times as much as the pressure in the cylinder of an engine that drives an average railway engine. Even the water is compressed and bodies into which the water cannot penetrate quickly enough are squeezed almost beyond recognition when they are sunk

to great depths. The *Challenger* explorers found that a piece of wood sunk to the abysses was so heavy when pulled up again that it sank in water. The muscles of a dead animal, such as a whale, must undergo a tremendous compression if the carcass sinks.

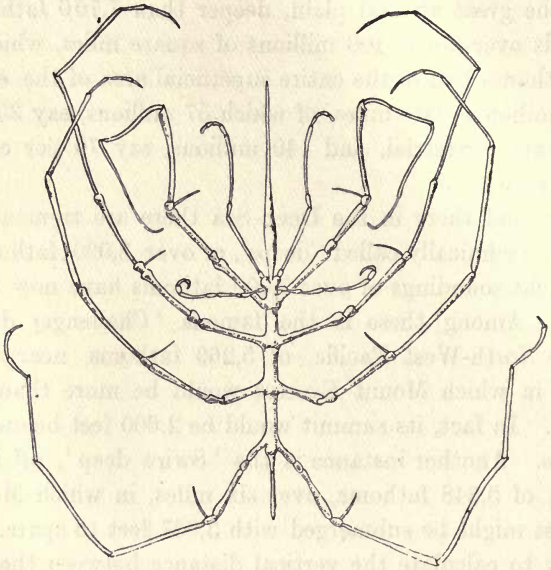


FIG. 28.—Deep-Sea Pycnogonid or "Sea Spider," Pipetta, with extraordinary length of limb in proportion to the size of the body. The males carry the eggs. (*After* Loman.)

When a whale fills its lungs and 'sounds', remaining below the surface for ten minutes at a time (as the Prince of Monaco proved), its body may be subjected to a considerable increase of pressure, which the ribs in particular have to withstand. Mr. J. Y. Buchanan suggests that the occurrence of a number of broken and repaired ribs on one

side of a whalebone whale's skeleton preserved in the Museum of Monaco may be a record of the animal's having gone beyond the limit of safety. He recalls Paul Bert's experiment, in which the pressure of the air in the lungs of a dog was reduced by a not very large fraction of an atmosphere, with the result that the thorax collapsed with every rib broken.

(3) *Temperature.*—The sun's heat is lost at about 150 fathoms, and the Deep Sea is therefore intensely cold. With relatively little variation (2° or 3° Fahr.) in the year, the temperature remains near the freezing point of fresh-water (32° Fahr.). The bottom temperature may be below 30° Fahr. in Polar waters, and over 90 per cent. of the whole sea-floor it may be said that an eternal winter reigns. What a contrast this is to the surface conditions, which may show an annual variation of 50° in one area, and which show such extremes as 26° Fahr. off Nova Scotia and 96° in the Persian Gulf! The variations and extremes on land are still more marked.

The coldness of the deep water seems to be mainly due to a flow of cold bottom-water from the Southern and Antarctic oceans towards the equator, and in a less degree to a similar flow from the sub-Arctic region. The causes of this flow are complex, but the oceanographers refer to the great intertropical evaporation, to the action of extra-tropical winds which blow the surface-waters polewards, to 'the head of water' which is accumulated in high latitudes by the action of the prevailing winds, and to the greater density of the water in high latitudes. As temperature affects the solubility of gases in water, cold water being able to absorb more than warm water, the polar waters contain more oxygen than elsewhere, and the

equatorial movement of bottom-water rich in oxygen must be of considerable biological importance for the animals of the Deep Sea.

(4) *Darkness.*—There is but little penetration of light beyond 250 fathoms, so that the world of the Deep Sea is in utter darkness, save only in so far as that is relieved by gleams of 'phosphorescent' light. In some places where there is much of this luminescence, it may be that the scene is like the ill-lighted suburbs of a town on a very dark night, or like a moorland with no light save from the stars. In his 1911 cruise on the *Michael Sars*, the late Sir John Murray found that the light limit had been under-estimated. By using more delicate apparatus, notably the Helland-Hansen photometer, he was able to show that there is a clear effect at 300 fathoms, and some effect at 500 fathoms, which is about half a mile down. At 900 fathoms no effect of light was detectable. These were very sensitive tests, however, and for practical purpose we may still say that there is very little light below 250 fathoms.

(5) *Calm and Silent.*—Another physical feature is the pervading calm, for the severest storms are shallow in their grip, and though the cold polar water is ever creeping along the bottom towards the equator, this is a relatively slow movement. Only in a few places is there evidence of what may be called a current. If there were rapid movement the deep ooze which covers vast areas of the sea-floor would be raised in whirling clouds. Thus we must think of the deep sea as extraordinarily still and quiet, for there can be no noise to break the abiding silence of the abysses.

(6) *Monotony.*—There is some variety in the composition of the sea-floor, for the remains of calcareous organisms

predominate in some places and of siliceous organisms in others, and the debris called 'red clay' is found in the deepest parts of all. But otherwise monotony prevails. There is no scenery, except that here and there a ridge stretches like a watershed, or a volcanic cone rises abruptly to the surface, or a great depression leads into one of the 'deeps'. Otherwise there are great stretches of undulating plain, like very flat sand-dunes, or like a great desert. There is no sound and echo, no day and night, no summer and winter in the monotonous Deep Sea. It is all silence, all night, all winter. Apart from the animals altogether, what a remarkable picture rises in the mind—a picture of the forever unseen—a strange, dark, cold, calm, silent, monotonous world!

Biological Conditions

(*a*) The first big fact, the establishment of which we owe to the *Challenger* expedition, is that there is practically no depth-limit to the distribution of animal life. Wherever the long arm of the dredge has been able to reach, there are organisms and plenty of them. It is astonishing to read of Sir John Murray and Dr. Hjort using an otter *trawl*, with fifty feet of spread, at a depth of 2,820 fathoms (over three miles), and using it very successfully. It should be noticed that there are some thinly peopled areas—sea-floor deserts, so to speak; that there is a richer population at the more moderate depths; that there are more animals on the calcareous ooze than elsewhere; and that there are probably thinly-peopled zones between the bottom and the light-limit. But the big fact is that there is no 'deep' too deep for life.

(*b*) *Plantless.*—The second big fact is that, beyond the sunk resting stages of some simple Algæ, there are no plants in the Deep Sea. This follows from the absence of light, and it involves as a consequence that all the Deep-Sea animals must be either carnivorous or devourers of debris. There are the usual ' nutritive chains '—abyssal fish eating abyssal crustacean, and that eating worm, and that eating still smaller fry; but since they cannot all be eating one another there must be some extraneous food-supply. That is afforded by the gentle and ceaseless rain of small organisms, killed by vicissitudes in the pelagic meadows overhead, and sinking through the miles of water like snowflakes falling on a very still day. Investigation all goes to show that while big corpses like those of fishes are doubtless all to the good if they reach the bottom undevoured, what counts for the Deep-Sea basal food-supply is the rain of microscopic atomies.

(*c*) *No Bacteria.*—There are abundant bacteria in the sea, in the economy of which they play a very important rôle, but there seem to be none in the great abysses. It is interesting to know of one place in the wide world where there are no microbes. From their absence it follows that there is no rottenness; everything is devoured in the great clearing-house. The whale's carcass is picked bare, by crustaceans in particular; the skeleton is dissolved away till only the stone-like ear-bones are left. Of the great shark everything soon disappears save the teeth.

(*d*) *Representative Fauna.*—The animal population of the abysses includes representatives of most of the classes of animals from Protozoa to Fishes. Let us run through the list. There are many kinds of Foraminifera and a few Radiolarians (not including, of course, the sunk shells of

surface forms of both these types); there are many siliceous sponges, but no calcareous ones; there are sea-anemones and some related corals and very decorative Alcyonarians; Annelids and some other 'worms' burrow in the ooze; Echinoderms abound—starfishes, brittle-stars, sea-urchins, sea-cucumbers, and sea-lilies swaying on their stalks like daffodils by the lake-side; Crusta-

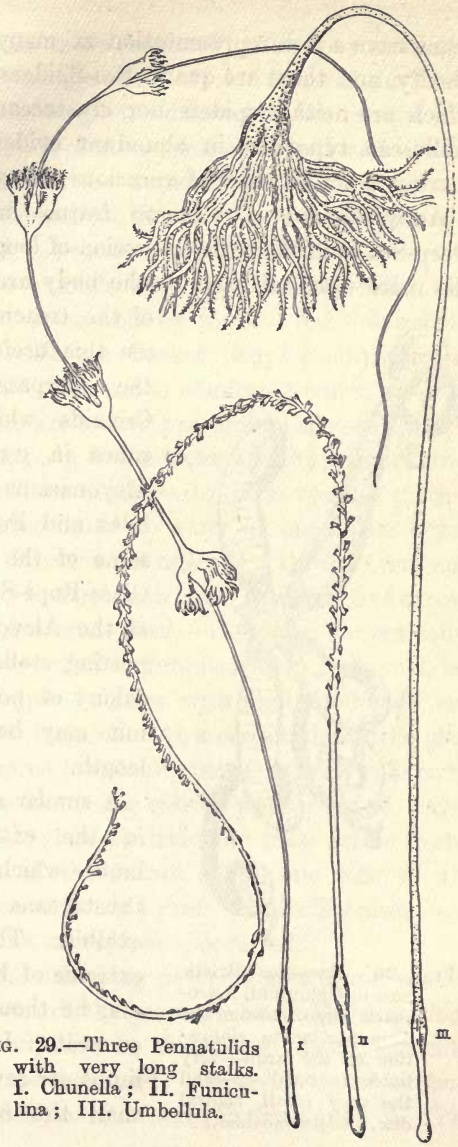


FIG. 29.—Three Pennatulids with very long stalks. I. Chunella; II. Funiculina; III. Umbellula.

ceans have a rich representation at many levels of complexity, and there are quaint Sea-Spiders or Pycnogonids which are neither spiders nor crustaceans; most of the molluscan types are in abundant evidence; and finally there is a weird army of voracious abyssal fishes.

Adaptations.—A common feature in the sedentary Deep-Sea animals is the possession of long stalks on which the more essential parts of the body are raised high out of the treacherous ooze. We see this useful adaptation in the surpassingly beautiful Crinoids which grow sometimes in great beds, in Alcyonarians such as Umbellulas and Funiculinas, and in some of the sponges like the Glass-Rope-Sponge. In some of the Alcyonarians the supporting stalk which bears the colony of polyps on its summit may be over a yard in length.

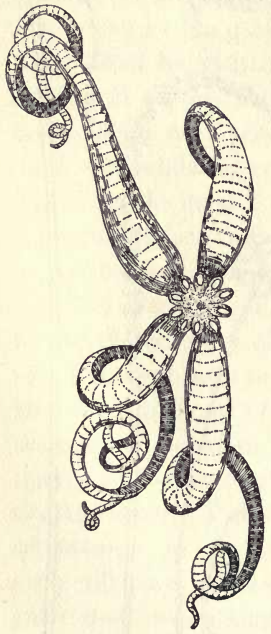


FIG. 30.—Deep-Sea Brittle Star or Ophiuroid, Astrocharis virgo, showing the disproportionate elongation of the arms—very liable to breakage—and the very small central disc. (*After* Koehler.)

A similar adaptation is seen in the extraordinarily long limbs which many of the Crustaceans and Sea-Spiders exhibit. They illustrate an extreme of lankiness and they may be thought of as walking on stilts. In many cases the limbs are several times longer than the body. There can

be little doubt that these elongated limbs are suitable for moving delicately on the soft surface. Some of the Deep-Sea Brittle-stars show a great reduction of the central disc and a great elongation of the arms as compared with shallow water forms. It may be noted that the extraordinary elongation of limbs and the like is quite incompatible with any conditions except those of perfect calm.

Many Deep-Sea animals are very delicately built, with bodies thoroughly permeable by water. A delicate structure like Venus's Flower Basket (Euplectella) which is shivered in a child's fingers, is admirably suited to great depths where there are tons of pressure on the square inch. The whole body is open to the water and the pressure is not felt. For while a hermetically sealed glass vessel is crushed in when it is lowered into deep water, an open glass vessel, no matter how delicate, is not affected. On the *Challenger* expedition, Mr. J. Y. Buchanan made an instructive experiment which has been often cited. He took a hermetically-sealed empty glass cylinder, wrapped it up in flannel, enclosed it in a copper cylinder with perforated ends, and lowered it to 2,000 fathoms. At a certain depth the glass cylinder was shivered into snowy powder, for its walls could not withstand the increasing outside pressure of the water. The shivering took place so suddenly that before water could rush in to fill the vacant space, one side of the copper cylinder caved in. As Prof. Wyville Thomson said, an 'implosion', not an explosion, occurred.

When an abyssal fish rising suddenly gets into a zone of much reduced pressure, the gas in its swim-bladder, which had its pressure adjusted to the greater depth, expands, and the fish, in spite of itself, is hurried to the surface, 'tumbling upwards', as Professor Hickson puts it. The

transition is too rapid for a readjustment to be effected. It is well known that Deep-Sea fishes brought up in the dredge are apt to suffer explosion and distortion in the ascent.

Another adaptation that leaps to the eye is the specialization of tactile appliances, as is natural enough in a world of darkness. There may be antennæ longer than the whole body, groping a long distance ahead, so that the animal can feel its way as a blind man does with his stick. Many of the long legs of crustaceans bear tactile bristles and many of the fishes have long slender barbules stretching backwards from the chin or from the fins. They are often well-innervated and their suitability for the conditions is evident enough.

An Extraordinary Deep-Sea Cuttlefish.—As an example of an extraordinary abyssal type, we may take *Cirrothauma murrayi*, one of the captures of the *Michael Sars* North Atlantic Deep-Sea Expedition of 1910, which was carried out under the auspices of the Norwegian Government and the superintendence of the late Sir John Murray and Dr. Johan Hjort. Three thousand metres of wire were out when this new cuttlefish, which has been carefully described by Prof. Chun, was captured, and it is a wonder that it came up in a condition to be examined. For its fragility recalled that of a Ctenophore, which is saying a good deal; the body was gelatinous and semi-transparent; a delicate web united the arms, through the whole length of which the nerves could be seen shining. The gelatinous body had an exceedingly faint violet colour, while the parts round the mouth and the basal portions of the arms showed the purple chocolate colour which occurs in many Deep-Sea animals. While most cuttlefishes are covered with chroma-

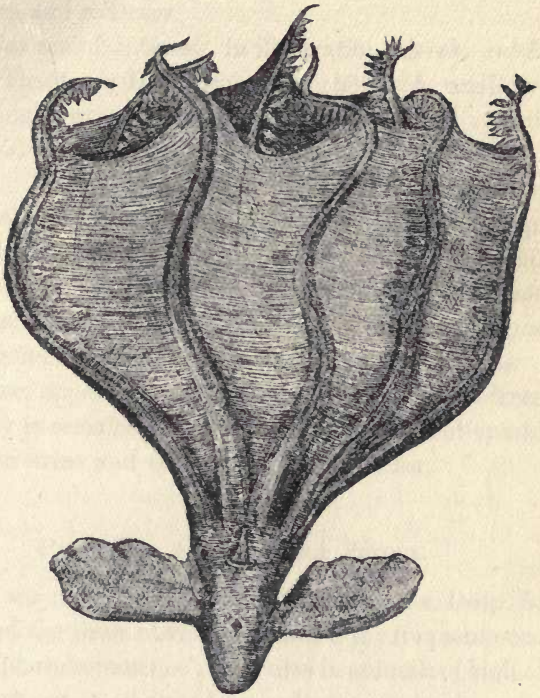
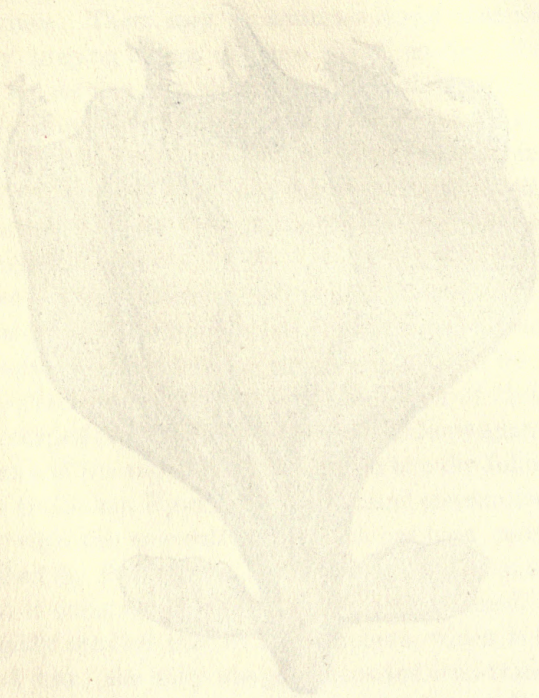


FIG. 31.—Deep-sea Cuttlefish, Cirrothauma murrayi. (*After* Chun.)



tophores, this denizen of the great depths had only one, 'a rhombic chromatophore between the two fins'. The arms bore some normal suckers, but each had thirty-six others of minute size, flattened and without sucking disc, and showing in each case in the long spindle-shaped and clumsy stalk a curious structure which may be a luminescent organ and reflector.

The eyes are of interest, in illustration of—*the subtlety of life.* There are Deep-Sea cuttlefishes with small eyes, as one might expect, but this is the only case, recorded as yet (1914), in which the actual structure of the eye is involved. For this cuttlefish is blind! The eye is minute, without a lens, with a very degenerate retina and optic nerve. Nature is economical, as we say in metaphor; but here she seems to have been parsimonious to a degree almost hazardous. The degeneration of this Cephalopod's eye has gone further than in many blind vertebrates. It is adaptive, apparently, to conditions of abyssal darkness; but surely it remains sensitive to the luminescent sparkles of its own arms and the prey they grope for.

Problems of Deep-Sea Fauna.

There are many unsolved problems in the Deep Sea, and one of the most obvious of these is the frequent occurrence of 'phosphorescence'. It is seen in animals of high and low degree; it is exhibited by sedentary animals and by free swimmers; it is associated with a great variety of highly specialized organs; and these are occasionally situated on most extraordinary places—near the end of the tail, on the tip of a long flexible rod, inside the mantle-cavity of a cuttlefish, or inside the gill-chamber of a crusta-

cean. It is so common that it surely has some significance.

Perhaps it has different meanings in different animals, and there is no lack of suggestions. May it be sometimes a lure, attracting victims, who come like moths to the candle ? Is it sometimes an advertisement on the part of unpalatable creatures, warning off intruders and molesters, as the rattlesnake does with its rattle ? Does it sometimes serve as a lantern, guiding the active animal to its prey ? Of course that would not apply to cases where the light is at the hind end ! Does it serve in some cases as a ' recognition mark ', enabling those of the same kin to know one another ? In some fishes the disposition of the luminescent organs on the body is different in the two sexes. But phosphorescence, as it is called, remains an unsolved problem.

Another difficulty is raised by the fact that there is so much colour in Deep-Sea animals. What can be the use of that in an abode of darkness ? There are many reds, e.g. in Crustaceans and Anemones ; there are shades of orange and yellow ; there are some instances of beautiful blue ; there is almost no green. It is noteworthy that there is very little in the way of spots or stripes, most of the animals being all one colour. It is probable enough that there is no utilitarian interpretation of these Deep-Sea colours, which may be simple by-effects of useful structures and functions. It may be that the Deep-Sea colours are like those in withering leaves—without utility in themselves.

The autumn colouring of withering leaves is largely due to the ebbing vitality, just as floral colouring is largely due to intense vitality. Decomposition products in the former, waste products in the latter may not be chemically far apart. But while the pigmentation of the flowers is turned

to good account as a means of attracting insects, no one has ever suggested any utility in the gorgeous colours of the autumn woods. They are the outcome of very important physiological processes, but they are not themselves of use; and the same is probably true of the reds and other bright hues of many abyssal animals.

Another general problem—the most general of all—is raised by the fact that many Deep-Sea animals are quite closely related to shore animals, with essentially the

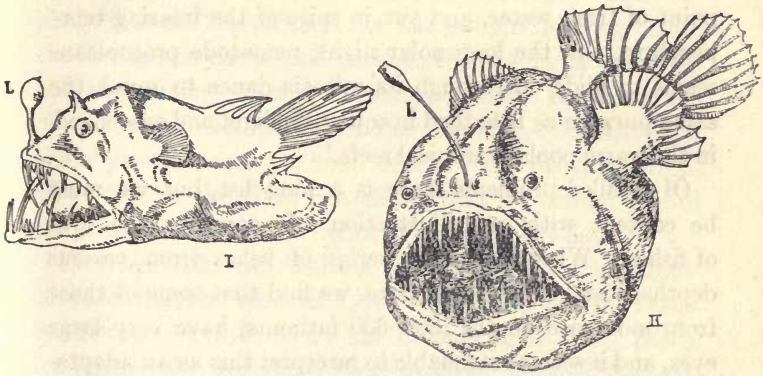


Fig. 32.—Two Deep-Sea Fishes. L, Luminous organ.

same functions discharged by essentially the same organs, and yet under such different conditions of temperature and pressure. Processes of digestive fermentation, for instance, which go on in shore animals in the warmth of the Tropics, are also going on on the floor of the Deep Sea at a temperature near the freezing-point of fresh water. We know that warmth up to a certain limit hastens growth; we should like to have facts in regard to the rate of growth in the eternal winter of the Deep Sea.

In reporting on the free-living marine Nematodes collected at Cape Royds on the Shackleton Expedition, Mr. N. A. Cobb refers to the same problem of vigorous life in extraordinary conditions. Hundreds of specimens, males, females, and young, were taken from a mere thimbleful of the dredgings. They seem to be rather smaller than species in warmer seas, but they do not seem to be less prolific. 'It is hardly conceivable that the body temperature of the marine polar species is higher than that of the water in which they live, namely, near the freezing point of fresh water, and yet, in spite of the freezing temperature, and the long polar night, nematode protoplasm seems to glide on through its mitosis dance to much the same purpose as if bathed in equatorial light and ensconced in the warm pools of tropical reefs.'

Of detailed problems there is a long list, but we must be content with one illustration. It concerns the eyes of fishes. When we take a series of fishes from various depths, starting with the shore, we find that some of those from moderate depths (300–600 fathoms) have very large eyes, and it seems reasonable to interpret this as an adaptation to the failing light. We also find that some of those from great depths, of over 1,000 fathoms, have very small eyes, and it seems reasonable to associate this with the darkness. A useless eye will tend to dwindle, for the individuals with least of it will get on best. But the difficulty is that, along with the abyssal fishes with very small eyes, there are others which have very large ones. It is difficult to see how both conditions can be adaptive. Two suggestions have been made: that those abyssal fishes with large eyes are relatively newcomers, in which the dwindling process has not begun, or that they are

adapted to make use of the gleams of phosphorescent light.

The Question of Origin.—As to the origin of the Deep-Sea fauna, the evidence points to the conclusion that the abysses have been persistently colonized age after age by migrants from the shore and from the 'Mud-Line'. There is a marked resemblance between certain representatives of the Deep-Sea fauna in a given region and representatives of an adjacent shore fauna. Quite a number of Deep-Sea animals have affinities with Polar animals. It is unlikely that the Deep-Sea fauna was established long before the Cretaceous times, and perhaps the cooling of the Poles and the setting up of a bottom-movement equatorwards of cold water rich in oxygen was one of the conditions of the abysses becoming a home of life. The rarity of primitive types in the Deep Sea shows that we cannot regard the fauna as made up of relics of very ancient days.

Professor Johannes Walther calls attention to the significant fact that no Palæozoic types occur in the present Deep-Sea fauna. Archaic forms like *Lingula* (lamp-shell), *Limulus* (king-crab), *Nautilus*, *Pleurotomaria*, *Mytilus*, *Serpula*, and *Astropecten* are littoral, not *abyssal*. The present-day Deep-Sea animals do not date back further than the Triassic period, and some of them are closely related to Cretaceous types. Walther works on to the interesting suggestion that the enormous elevation-movements which led to the Hercynian range in Europe, the Appalachians in America, and Sudanese mountains in Africa were associated with complementary depressions which formed the great abysses of the ocean.

The Wonder of the Deep Sea.—In one of his last writings Herbert Spencer complained of the unreflective

mood among cultured and uncultured alike, ' which does not perceive with what mysteries we are surrounded'. ' By those who know much', he said, ' more than by those who know little, is there felt the need for explanation'. ' What ', for instance, ' must one say of the life, minute, multitudinous, degraded, which, covering the ocean floor, occupies by far the larger part of the earth's area ; and which yet, growing and decaying in utter darkness, presents hundreds of species of a single type ' ? This raises the question of *the deeper significance of the abyssal fauna.*

In the first place, it seems useful to remind ourselves that a knowledge of the Deep Sea has cut into human life ; it has been *of value to mankind*, practically, in connexion with laying cables (and that has meant much) ; intellectually, for it has been an exercise-ground for the scientific investigator ; emotionally, for there is perhaps no more striking modern gift to the imagination than the picture which explorers have given of the eerie, cold, dark, calm, silent, plantless, monotonous, but thickly peopled world of the Deep Sea.

Yet this cannot be its full meaning. So perhaps we get nearer the heart of the problem when we recognize the simple fact that the Deep Sea is an integral part of the whole. Just as the making of the great ' deeps ' was correlated with the raising of great mountains, so the abyssal fauna is wrapped up with the whole vital economy of the Earth. For it is the overflow basin of the great fountain of life whose arch is sunlit. It is necessary to the wholesomeness of the ocean. It is the universal clearing-house.

And perhaps we may go a little deeper still, for when we recognize that insurgent life which will not be gainsaid has conquered the abyssal desert, that this by-way is full of

beauty not surpassed elsewhere, and especially that there is here the same order and rationality and pervasive purposiveness that we find elsewhere, then we begin to perceive that the life of the Deep Sea is part of the embodiment of what appears to us as a great thought. To the question of significance, which forces us far beyond Science, William Watson has given us the poet's answer :—

Nay, what is nature's
Self, but an endless
Strife towards music,
Euphony, rhyme ?

Trees in their blooming,
Tides in their flowing,
Stars in their circling,
Tremble with song.

God on His throne is
Eldest of poets,
Unto His measures
Moveth the whole.

IV. The Freshwater Fauna

The systematic study of the freshwater fauna began before that of the shore or of the deep sea, for men like Réaumur (1683–1757), Rösel von Rosenhof (1705–1759), and Trembley (1700–1784), who had the joy of discovering and naming some of the commonest inhabitants of our lakes and ponds, laid broad and deep foundations before there was much in the way of marine zoology. But when the fauna of the sea began to be systematically studied, attention was in great measure charmed away from the freshwaters, and it is only in the last quarter of a century or so that this haunt of life has begun again to receive its due share of investigation.

It is said that the freshwaters occupy about 1,800,000 square miles, but that is a small fraction of the total of about 197,000,000 for the earth's surface. In some countries, however, the freshwater area is very considerable; thus in Finland it is estimated at about 13 per cent. The relative smallness of the freshwaters is made up for in a way by the scattered distribution and the correlated great diversity in character. How many different forms there are, with no unity except in the word *fresh*—the large deep lake with storms like those at sea, the mountain tarn with its dark mysterious surface, the shallow pond with a population in many respects different from that of the lake, the ephemeral pool, the permanent well, the swamp, the ditch, the brook and the river. Nor do these exhaust the list; thus in a detailed German classification we find a special subdivision for water-pipe fauna. It is recorded that before the improvement of the filtering in connexion with the water-supply of a large town on the Continent, no fewer than sixty-one animals were obtained from the pipes—including eels, sticklebacks, water-snails, insect larvæ, worms, and the freshwater sponge. For practical purposes, it may be noted, large intruders are often unimportant. The serious thing is when some fungus, like Crenothrix, takes up its abode in the pipes.

Of the various forms which accumulations of fresh water may assume, the lake or loch is most important. It is distinguished from the pond not so much by its size as by depth, which reaches a maximum in Lake Baikal, with its 760 fathoms. In typical lakes we can readily distinguish (1) the relatively shallow shore-area, (2) the open water, and (3) the dark quiet dreary plain at the foot of the steep slope or talus which runs from the shore-shelf downwards.

Thus in true lakes, as in the sea, we have to distinguish a littoral, a pelagic, and an abyssal fauna.

Physical Conditions.—The physical conditions of freshwater basins are of course very diverse, and they determine noteworthy differences in the fauna and flora. Thus it is well known that certain organisms, such as the stonewort Chara, and the freshwater crayfish, Astacus, require that there be a relatively large percentage of carbonate of lime in the water, while others, like the freshwater mussels, do not thrive if there is.

Concerning temperature, it is obvious that in summer that of the surface is higher, while in winter, especially when there is ice, that of the bottom is higher. Averages on the surface for the four seasons read like this: Spring 6·7° C., Summer 17·8° C., Autumn 11·9° C., Winter 3·9° C. In summer, or indeed for about 280 days in the year, when the warmer water is at the top, there is a decrease down to 4° C., the temperature of water at its greatest density, but the decrease downwards is not uniform—there being a strange leap between 5 and 10 fathoms. In winter, for about 85 days in the year, when the colder water is at the top, there is an increase downwards until 4° C. is reached. For a short time twice a year, the temperature is practically uniform throughout. It should also be remembered that for each 5 fathoms there is almost an additional atmosphere of pressure.

The degree of illumination is of vital importance as regards the distribution of both plants and animals, and the depth to which light can penetrate varies considerably, especially with the purity and colour of the water. The red rays are lost first, the violet rays go deepest. A common average result with a white plate is that it ceases

to be visible at about 3 fathoms, but we have to multiply this by two since the light has to travel up again from the plate, so that a common average for light-penetration is 6 fathoms. In very clear water, as in the Lake of Constance in winter, the figure may rise to over 12 fathoms. And this must be further extended if we take the chemical rays into account, for silver chloride paper is affected at 55 fathoms and silver bromide paper at over 90 fathoms.

The diverse coloration of freshwater basins raises a number of interesting and difficult questions. Chemically pure water is said to have an azure blue colour. The addition of numberless impalpable dust particles produces a yellowish tint, which along with the primitive blue gives green. Thus we have to thank the dust for the colour of the lake as well as of the clouds overhead. But the green is often in part due to millions of unicellular Algæ. A tawny yellow, familiar in the rivers of the Scottish Highlands, may be produced by abundance of dissolved organic matter—humic acid and the like. A most remarkable iridescence of water is sometimes seen when the surface is covered with millions of the translucent moulted cuticles of water-fleas, but the splendour of this has to be seen to be believed. The practical importance of the colour of the water is in connexion with its penetrability by light; the blue water is most penetrable, the green less, the yellow still less.

Various Lacustrine Regions.—The littoral or shore area of the lake may be broad or narrow according to the configuration of the lake. Like the corresponding seashore area, it is subject to great vicissitudes—diurnal and seasonal, it is often full of movement, it is strongly illumined, it has a rich vegetation, and it is often crowded with

animals. It is marked by such plants as the stonewort (*Chara*), mare's tail (*Hippuris*), pond-weeds (*Potamogeton*), duckweed (*Lemna*), water-lilies, *Ranunculus lingua*, *Alisma plantago*, bog-bean, and so forth. Some show interesting adaptations of mobility and elasticity suited to the turbulence of the shore.

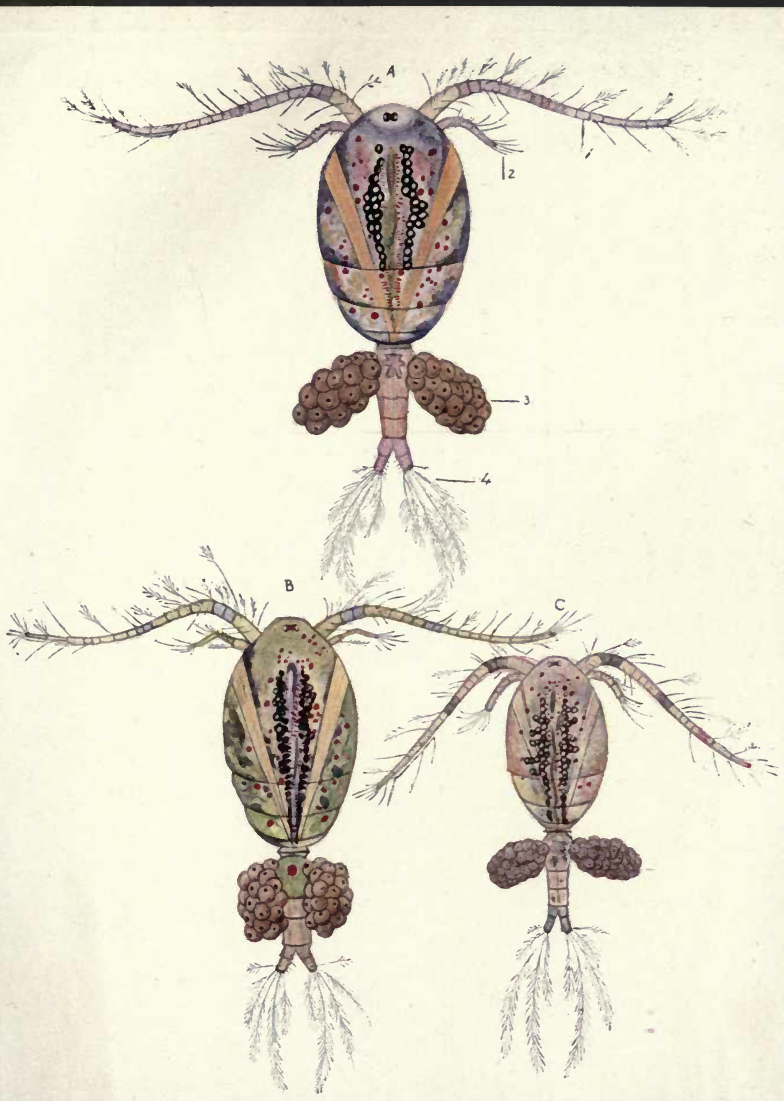
As to the animal life, it is varied. By the shore there may be nests of gulls and wild duck, of coot and moorhen. The shallows are the home of frogs and sticklebacks, of carp and miller's thumb (*Cottus gobio*). The freshwater mussels plough their leisurely way along the mud; the water-snails glide back downwards along the surface-film. The water-spider weaves her diving-bell nest, and beautifully coloured water-mites rush to and fro. There are countless Crustaceans, like *Daphnia* and *Sida*, *Diaptomus* and *Cyclops*; fixed Rotifers like *Floscularia* and *Melicerta*—miracles of beauty; some equally fascinating freshwater Polyzoa; simple Planarian worms wafting themselves along the water weed by their unseen cilia; besides Hydra and freshwater sponges and many Protozoa. We have given samples enough to show that the shore of the lake has a very representative fauna.

The second great region in lakes is the open water, tenanted by a pelagic or limnial fauna and flora. The vegetation is represented by numerous Algæ, by duckweed and *Ceratophyllum*, by the beautiful rootless Bladderwort (*Utricularia*) with its neat traps for water-fleas. Some show gas vesicles which ensure floating. As to animals, there are Infusorians (e.g. species of *Ceratium* and *Peridinium*), numerous Rotifers, legions of water-fleas, not a few water-mites (such as *Atax crassipes* and *Curvipes rotundus*), a few insect larvæ, e.g. of *Corethra*

plumicornis, and also the larval stages of some shore forms, e.g. of the bivalve *Dreissensia*. In the transparency, the delicacy of build, and the occasional presence of long processes—believed to be useful in drifting—we see adaptations to the open water life.

The success of a lake depends to a large extent upon the open water population, and waxes and wanes with its vicissitudes. A few forms are almost uniformly abundant all the year round, but the majority show a marked periodicity. Thus the Rotifer *Synchæta* has its climax in spring, and there may be about three millions to the square yard in April. The well-known Diatom, *Melosira varians*, has two maxima in the year, one in July and one in October, and may attain in the last-named month to the astonishing abundance of about 7,000 millions to the square yard. The slimy Alga, *Clathrocystis aeruginosa*, has its climax about August, with about 500 millions to the square yard. Others, again, have their maximum in winter, such as the Copepod Crustacean, *Diaptomus gracilis*, whose proportionate representation for the four seasons is indicated by the figures—760 for April, 7,900 for August, 31,160 for September, and 121,290 for January. The broad fact to be realized is that the upper layers of the open water are the chief productive areas, where the Algæ utilize the energy of the sunlight to build up the carbon-compounds which form the fundamental food supply of all the lacustrine population.

The third great region is that of the greater depths of the lake, a region of uniformity, where there is neither day nor night, where the temperature is low and relatively uniform, where the pressure is very great, where there are no movements apart from life, and where there is usually


A
2
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much mud. It is the least populous region. Since it is dark, there are practically no plants except Bacteria and the like. The animal population includes Amoebæ and their relatives (e.g. species of *Difflugia* and *Arcella*), Infusorians like *Stentor* and *Vorticella*, a deep-water reddish Hydra, simple Turbellarian and Nematode worms, others of higher degree like *Nais*, some species of *Fredericella* and *Paludicella* among Polyzoa, a number of Crustaceans (e.g. blind species of *Cyclops* and *Asellus*), some insect larvæ, e.g. of the harlequin fly, a few water-mites like *Hygrobates*, a few molluscs like the bivalve *Pisidium hoferi* and the Gastropod *Limnœa abyssicola*, and finally a few fishes like the giant Silurus and its small counterpart, the burbot (*Lota vulgaris*), which is one of the hosts of the young stages of the formidable human tapeworm (*Bothriocephalus latus*), thus linking up the dark depths of the lake into connexion with human life.

In regard to other freshwaters, such as ponds and rivers, it must suffice to say that each has its distinctive fauna, and that the population in rivers is much less abundant than elsewhere. In the actual current of the Rhine, Lauterborn found only twenty Rotifers, two Crustaceans, nine Protozoa, and two Diatoms; but of course this number is greatly increased when we take account of the creatures —e.g. larval insects—that creep about on the stones and among the weed. Wherever there is stagnancy, e.g. in the pools of the overflow bed, we find much the same fauna as in ponds. As to ponds, while there are a few forms, e.g. *Leptodora hyalina*, which occur both in ponds and lakes, the fauna of the shallow pond is usually quite different from that of a true lake. Thus no one expects to find a Crustacean like *Byotrephes longimanus* in a pond.

Inter-Relations.—There are many good instances among freshwater animals of the way in which the life of one creature becomes wrapped up with that of another. We shall afterwards refer to the extraordinary fact that the continuance of the race of freshwater mussels depends on the presence of minnows and other small fishes, while on the other hand, the continuance of the freshwater fish known as the bitterling (*Rhodeus amarus*) depends on the presence of freshwater mussels. The young stages of the liver-fluke of the sheep are spent within the small freshwater snail (*Lymnæus truncatulus*), and the larvæ of the formidable guinea-worm of man are found inside certain species of water-flea or Cyclops. Some tropical freshwater fishes feed greedily on the aquatic larvæ of mosquitoes and thus help to lessen malaria which is due to a microscopic animal temporarily parasitic in the insects. There are endless nutritive chains of great practical importance. Thus the voracious cormorants so often shot down on the shores of the estuary, where they certainly engulf many fishes, are not to be dismissed so summarily, for in certain localities they keep down the eels and crabs which destroy the fry of valuable species. Some freshwater fishes feed on crustaceans and insect-larvæ, which feed on minute organisms, which, again, depend on decaying organic matter. The insectivorous bladderwort (*Utricularia*) catches small animals in its neat traps and these are said to be utilized by the water-spider. As we shall see, some caddis-worms spread nets for the 'dwarf-plankton,' and the green freshwater Hydra owes its colour and its success to having entered into partnership with very minute Algæ which live within the cells of its inner or endodermic layer.

Adaptations.—Many freshwater animals run the risk of being periodically dried up, and there is a series of remarkable adaptations to meet this vicissitude. Many are able to survive prolonged desiccation. They are masters of the art of 'lying low and saying nothing', as Brer Rabbit phrased it. The capacity is illustrated by some Protozoa, Nematodes, Rotifers, Bear-Animalcules, Entomostracan Crustaceans, and Mites, but in some cases what survives is not the animal itself but an enclosed egg or germ.

Writing in the *Annals and Magazine of Natural History* in 1898, Mr. Atkinson noted that forty years before he had taken some samples of mud from the ancient pool of Gihon, outside the Jaffa Gate of Jerusalem, which at that time contained water for only two months of the year. The dry mud was sent to England and moistened, with the result that Dr. Baird found in the culture six new species of living Entomostraca or water-fleas. For eight years in succession, at the Leeds Philosophical Society's Museum, the mud was dried up in summer and moistened again in spring, and its tenants still persisted. Not that any one individual was known to persist, but multiplication in summer always provided individuals or resting eggs to carry on the torch for another period. In one case, a small sample was left dry in a pill box for nine years, and then moistened, with the result that in a fortnight a single specimen of *Estheria gihoni* made its appearance. Here the torch was kept burning, either by an individual or more probably by a resting egg, throughout the desiccation of nine years. In another case, the alternation of drought and moisture was kept up artificially for twenty-four years, with unvarying success as regarded persistence of vitality.

It is well known that specimens of the brine-shrimp (*Artemia*) can often be got by keeping a solution of Tidman's Sea-Salt for some days till the desiccated germs hatch out.

Belonging to another series are the adaptations which enable freshwater animals to meet the winter, which in northern countries sets a spell on many forms of life. It sends many to sleep, like the frog in the mud by the pond side—mouth shut, nostrils shut, eyes shut, breathing by its skin like a worm, and with its heart beating ever so feebly. It sends others to the deeper sleep of death, for just as winter prunes the trees, so it sifts the fauna of the pond. There is severe elimination, and it is therefore very interesting to notice the ' winter-eggs ' of water-fleas and Rotifers which are able to withstand great severities of temperature, and the strange ' statoblasts ' or resistent germs of Polyzoa, and similar adaptations for surviving difficulties by a Fabian policy of waiting. A good example is the freshwater sponge, which spreads exuberantly over stones and submerged roots in the summer, but soon feels the pinch in autumn. The body of the sponge dies away, and rots away, but in the skeletal framework, which cannot rot, clumps of cells are formed, buttressed round by capstan-like flinty spicules, and these *gemmules*, as they are called, persist as foci of life while the parental corpse disintegrates. When the spring comes and the rivers are in flood after the melting of the snow, the sponge skeleton is broken and the gemmules are carried hither and thither, many, perhaps most, to destruction, a few to find a harbour in suitable crevices where they may proceed to develop into early summer sponges.

In times of severe frost many animals seek safety in the mud—a refuge from being imprisoned in the ice. There

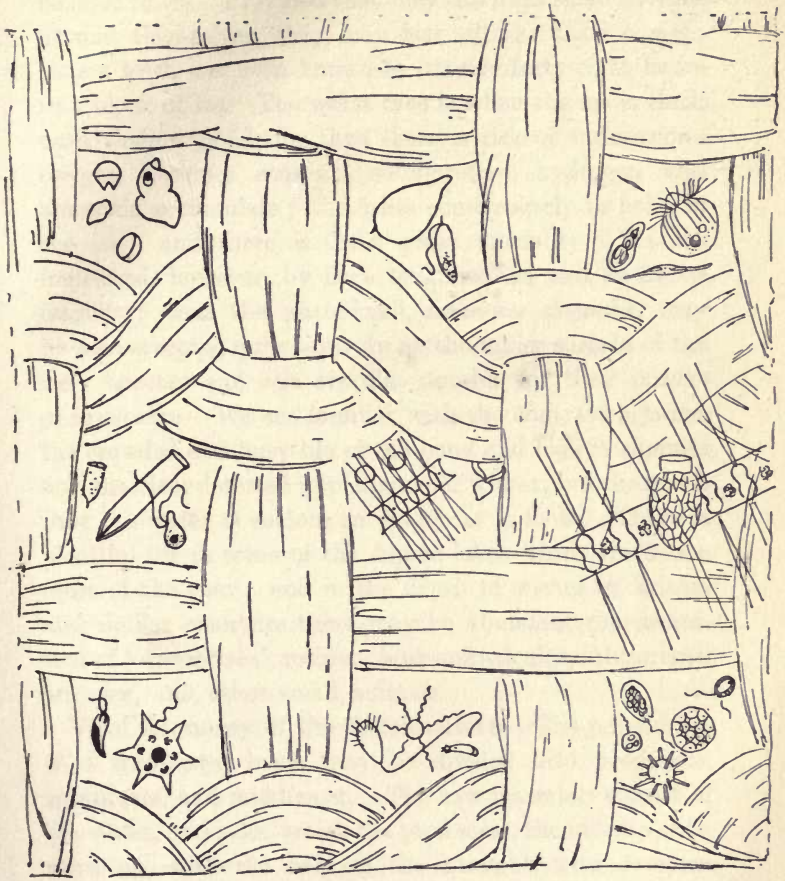


FIG. 34.—Magnification of a piece of fine 'Müller's gauze' used in tow-netting, showing the organisms of the dwarf plankton or 'Nannoplankton,' which are minute enough to pass through the invisible pores of the cloth. (*After* Lohmann.)

is undoubtedly severe elimination, but there are some tough creatures which do not necessarily die even when encased in ice. Provided that they can form small cavities around themselves, they may last till the thaw comes; thus a leech has been known to survive forty-eight hours in a block of ice. The worst case is when the ice is thick on a shallow pond, for then there is risk of suffocation; oxygen becomes scarce; sulphuretted hydrogen and ammonia accumulate; the fishes come eagerly to holes in the ice; and there is often great mortality. We are impressed, however, by life's toughness as well as by its fragility; thus the water-snail, *Limnœus stagnalis*, may be seen creeping quite actively on the under surface of the ice. Leeches and eels are also notable for their powers of resistance. We are familiar with the contrast between the crowded and busy life of the pond and loch in summer and the clear deserted appearance in winter, but the fact is that the water is seldom so empty as it looks. There is plentiful life in some of the Alpine lakes which are frozen most of the year; and in the depth of winter in Britain and similar countries there may be abundant representation of 'water-fleas', rotifers, bear-animalcules, infusorians, amoebæ, and other small animals.

Vital Economy of the Freshwaters.—The population of a freshwater basin may be divided into producers, consumers, and middlemen. The raw materials consist of air, water, and salts, which the producers, the green plants, work up, with the help of the sunlight, into complex carbon compounds. These are utilized by the consumers, the animals, who dissipate the stores of energy which the plants have accumulated. The middlemen are in great part the Bacteria, which often make vegetable products

more available for animal use, and also break up the dead bodies of animals into material that can be used by plants as food.

Besides Bacteria there are other extremely minute forms of life which play an important part in the vital economy of the freshwaters. Such are the Desmids, Diatoms, Phyto-flagellates, and Zoo-flagellates—which Prof. Lohmann of Kiel sums up in the word Nannoplankton (or Dwarf-plankton). They are so minute that they pass easily through the meshes of the finest silk gauze, and they are best collected by centrifuging samples of the water at a high rate of speed. Their importance lies in their extremely rapid multiplication and in the fact that some of them are producers of the organic out of the inorganic, while others are middlemen between the dead and the living.

The securely established general idea of fundamental importance is that which Liebig did much to promulgate —the idea of the circulation of matter. Apart from a few permanent products like the Travertine of Tivoli, the oolitic material on the shores of the Great Salt Lake, and deposits of siliceous diatom-earth, everything about the lake is in a state of flux. Place a box with water, some mud, and some animal manure beside the fish pond, and arrange it so that there may be a periodic discharge from near the surface. Bacteria multiply and work their way with the manure; Infusorians multiply and form food for Daphnids and other 'water-fleas'; these trickle in a living cascade into the pond; the fishes are fed, and the fisherman's table is served. The chain may be longer or shorter; Diatoms, Rotifers, Worms and so on may share in the ceaseless reincarnation of material that goes on. If the

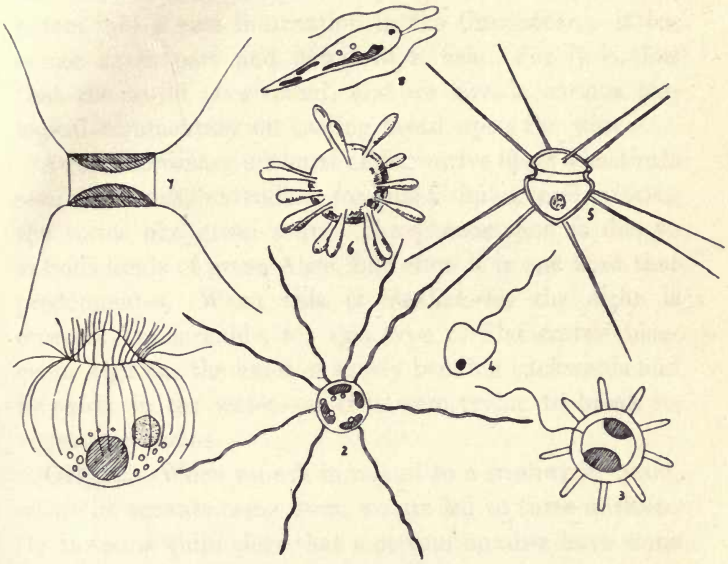
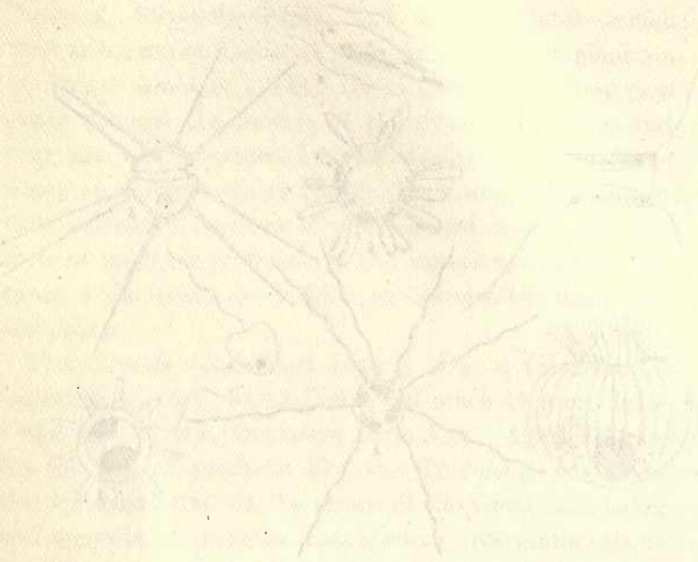


FIG. 35.—Microscopic organisms of the dwarf plankton or 'Nannoplankton.' (*After* Lohmann.) 1. Halteria rubra, a ciliated Infusorian, with a symbiotic Alga inside it. 2. Meringosphæra mediterranea, a unicellular Alga, with long projecting processes. 3. A Chrysomonad with projecting rods on its shell. 4. A Monad. 5. Cladopyxis setifera, a Peridinid Infusorian. 6. A Coccolith, Rhabdosphæra claviger. 7. A unicellular Alga, Chætoceras gracile. 8. Phytoflagellate, Eutreptia.



fisherman should have the bad luck to capsize his basket, he might get the contents back again after many days. The Bacteria reduce the dead fish to debris which Infusorians devour, and to simple substances which plants reintroduce into the circle of life. What was part of the dead fish becomes part of Infusorian and Diatom; it enters into a new incarnation in the Crustacean; it becomes again part and parcel of a fish. For it is thus that the world goes round, and we have a curious biological commentary on casting bread upon the waters.

An extraordinary outburst of vegetative life is sometimes seen in canals, extending for many miles, and making the water like green soup. The phenomenon is due to various kinds of green Algæ, but often it is one kind that predominates. When this is *Oscillatoria*, the sight is especially remarkable, for this type of filamentous blue-green Alga has the habit of slowly bending backwards and forwards in the water—as if it were trying to break its vegetative chains.

Origin.—When we ask in regard to a freshwater basin, where its tenants came from, we are led to three answers. (1) It seems quite clear that a certain number have come from the sea, either by active migration, as we see the elvers doing to-day, or by passive transport as in the case of the freshwater sponges. When we find one family of sponges (Spongillidæ) in freshwater, and a large number of families in the sea, we may safely conclude that the freshwater forms had a marine ancestry. Hydra and half a dozen other Hydrozoa live in freshwater; all the other Cœlentera or stinging animals are marine; we need have no hesitation in regarding the freshwater forms as derived from marine ancestors.

It seems very likely that not a few of the freshwater animals have migrated gradually from the sea and the seashore, through estuaries and brackish water, to rivers and lakes. As the possibility of making this transition depends on the physiological constitution of the animal, we can understand that similar forms would succeed in different areas. And this is part of the explanation of the high degree of uniformity seen in the freshwater faunas of widely separated areas. The process of migration may be seen going on at present in the invasion of the Kiel Canal and in some similar cases. Various shrimps and the like go far up certain rivers; the flounder is found many miles from the sea; sticklebacks seem to be quite capable of thriving well in either fresh water or salt; and there are hundreds of similar facts.

(2) It has been suggested by Credner, Sollas and others that some present-day lakes are dwindling remnants of ancient seas—relict-seas in short. Part of an old sea may become land-locked and be converted in course of time into a freshwater basin. Or it may be that a present-day lake which never was as such part of a sea, may become connected with a relict-sea by alterations of land-level and owe part of its fauna to that circumstance. There may have been a somewhat uniform pelagic fauna in the remote past, and that may be part of the explanation of the uniformity of the fauna in freshwater basins widely separated from one another. If the land-locked portion of sea was gradually converted into a freshwater basin, there would be a stern elimination of non-plastic types, and since the conditions of elimination would be much the same everywhere, the result would be uniformity in the survivors. Mr. J. E. S. Moore has brought forward

strong evidence to show that the fauna of Lake Tanganyika includes many molluscs, for instance, which were inhabitants of Jurassic seas. It is very striking to find in Lake Tanganyika a Gasteropod like *Typhobia horei*—whose kinship is certainly with marine types.

Several different kinds of freshwater Medusoids (*Limnocodium*, *Limnocnida*) are known from various parts of the world, and are probably to be interpreted as relicts of a marine stock. The same may be said of the very simple freshwater polyp, *Microhydra ryderi*, reported from North America and also from Germany. Like numerous marine hydroids, but unlike the common freshwater Hydra, it liberates a minute swimming-bell or Medusoid.

It is necessary to distinguish between relict marine faunas and relict seas. Thus the remarkable population of Lake Baikal seems to be in part a relict marine fauna, but there is no evidence in the surrounding deposits to show that the Lake was ever anything but a freshwater basin. We must therefore suppose that the marine types in the lake—the seals, for instance—migrated from an ancient sea, along paths now hidden.

Thirty-four fishes are known from Lake Baikal, and L. S. Berg divides them into those which are general in Siberian freshwaters (17) and those (also 17) which are endemic. Of the latter some are related to Siberian forms, while others (Abyssocotini, Cottocomephoridæ and Comephoridæ) seem quite unique. There are no forms in the Siberian waters, nor in the Arctic Ocean, nor in the Pacific which come near these puzzling forms which Berg regards as very ancient, and perhaps native (autochthonous) to the Lake. They live at greater depths than any other freshwater fishes, descending to 1,600 metres.

(3) Of many of the smaller animals in a freshwater basin, it is safe to say that they have been transported from some similar haunt. The same or similar species occur in basins separated by half the circumference of the globe. And just as there are distinctive species of mammals and birds in islands—e.g. the Orkney Vole and the St. Kilda Wren —so there are distinctive species of crustaceans and fishes in lakes, the explanation being in both cases the same, that local variations have been helped *by isolation* to become stable species. A very striking instance may be found in the large number of different species of char in British lochs.

To explain the widespread faunistic uniformity in freshwater basins, Darwin referred to the agency of birds in carrying organisms or germs of organisms from one freshwater basin to another, from one watershed to another; to the wafting powers of the wind; and to changes of land level which may bring different river beds into communication. The capture of one river-valley by another running in a different direction has often occurred, and may have helped to distribute lacustrine types. It is probable, however, that birds have been the chief agents in transport. The startled duck that rises in a hurry from the water often carries some entangled aquatic plants with it, and animals on the plants. Thus another pond may be peopled. In the clodlets of mud on the feet of birds many minute animals have been found—Ostracods, Phyllopods and Copepods (all sorts of 'water-fleas' in short), Polyzoa and Rotifers, and Nematode worms. No fewer than 537 plants were found represented in 6¾ ounces of mud, and Darwin got eighty seeds to germinate from one clodlet from one bird's foot. The rôle of birds as distributing agents is well known to be very important for seeds, but

it is also very important for small animals. A diagrammatic instance may be found in the occurrence of a freshwater sponge in a pond in the middle of the sandy Sable Island which lies out in the Atlantic, a hundred miles from Nova Scotia.

From Land or Air back to Water.—There is a certain contingent of the freshwater fauna that has arisen by a sort of turning back of terrestrial and äerial forms. Just as whales and dolphins are in all probability the descendants of terrestrial mammals which took secondarily to the sea, so some freshwater animals, such as aquatic insects, the water-shrew and the water-vole, the otter and the beaver, are doubtless the descendants of terrestrial forms.

In this connexion it may be noted that many water animals are not so much wetted as one might think. In some water-beetles, such as the whirligig (*Gyrinus*) and the water boatman (*Notonecta*), the body is very partially wetted. In the water-spider (*Argyroneta*) considerable areas of the hairy body refuse to become wet. In the family of Hydrophilid beetles, some hardly wet at all, some keep considerable parts of the body dry, and some become wholly wet. The wetting or not wetting depends on capillary phenomena, which depend on the structure of the surface of the body and its hairs or setae. There can be little doubt that the differences are finely adaptive to slight differences in habit.

The Water-Spider.—In illustration of the interesting habits of freshwater animals we may take the case of the water-spider, *Argyroneta natans*, of which Dr. Wagner has made a fine study. It is remarkable as an air-breather which spends most of its life under water, and it is remarkable among spiders inasmuch as the male is much larger

than the female. The length of the male's body is about 15 mm. and that of the female about 8 mm. The colour is reddish-brown to olive-brown, but it has when swimming a silvery appearance due to bubbles of air which are entangled among the velvety hairs and shreds of silk which cover the body. It is in quiet pools where there are abundant water-weeds that this member of a thoroughly terrestrial race makes itself at home. There are a few other spiders, e.g. species of *Dolomedes* and *Pirata*, which creep down plants right into the water when danger threatens, and there are a few others which walk daintily on the surface-film, but *Argyroneta* is the only thoroughly sub-aquatic type.

It makes, as every one knows, a dome-shaped web, usually attached by silk threads, like a tent by its ropes, to water-weeds and stones, but occasionally fashioned inside a water-snail's empty shell, or in a hole in a piece of wood. In all cases it fills its dome with air brought down from the surface, till the result is something between a diving-bell and a submerged balloon. It has anticipated at least one of man's many inventions, though it is probably but dimly aware of its inherited or instinctive skilfulness. There is no hint of prentice-work in the web that is made in such peculiar conditions, and it is interesting to notice that the architecture bears a close resemblance to that of the webs made by terrestrial members of the same family. For some reason or other, the pattern worked out in winter is different from that of the summer web. The webs require frequent renewal, for inquisitive Gammarids and the like are continually breaking the moorings. The supply of air has also to be continually renewed. With this work and with the pursuit of the water-insects on which it feeds, the spider is kept busy, but it is able to spare a good deal of

time for its toilet—not exactly in combing its hair, as its movements suggest, but in arranging its lace, for it carries little tags of silk disposed over its body.

Unlike most spiders, Argyroneta is very peaceful, as if its residence in water had cooled its passions. When two meet they go quietly on, unless they are worried by captivity or happen to be very hungry—when, like creatures of higher degree, they are apt to be quarrelsome. The females are patterns of placidity, and are quite free from the reproach of devouring their mates or would-be mates, as their terrestrial cousins often do. It has to be remembered in this connexion that they are only about half the size of the males, the reverse of the usual relative proportions of the sexes among spiders. Within the silken bell the mother spider carefully disposes the cocoon containing the eggs, but when these hatch and the young spiders begin to fend for themselves, she ceases to show any interest in their movements. Wagner insists that she cares more about the cocoon than its contents, but it is very difficult to get mentally near these children of instinct, and it may be that the impression is as erroneous as that which might be made by a casual observer of mankind who, looking down from a great height, maintained that mothers seemed to give more attention to the cradle or the perambulator than to the content of baby.

V. The Terrestrial Fauna

The transition from water to dry land has been many times effected in the course of animal evolution. Among backboneless animals, it was negotiated by some of the Protozoa (Amoebæ and Infusorians) that passed from water to damp earth ; by some of the simpler worm-types (various

Planarians and Nematodes); by the earthworms and land-leeches; by a few Crustaceans, such as wood-lice and land-crabs; by the archaic Peripatus and its allies—widespread connecting-links between segmented worms and types like Centipedes; by the Centipedes themselves and their allies, such as Millipedes; by many Insects; by Spiders, Scorpions and many Mites; and by the Pulmonate Gastropods, namely land-snails and land-slugs.

While fishes are, of course, confined to the water, there are some interesting curiosities. Thus the eel may make short excursions over the moist grass of the meadow, and some tropical fishes burrow deep into the mud in the dry season. In the common Periophthalmus of tropical shores we have one of those extraordinary exceptional cases—a fish that can remain for many hours out of water. The same is true of the interesting double-breathing mud-fishes (Dipnoi), which have their swim-bladder turned into a sort of lung, and can live long out of water. Among backboned animals, the transition from aquatic to terrestrial life was made in the Carboniferous Period by the Amphibians, many of which still recapitulate every year the historically important step—passing from a larval or tadpole gill-breathing life in the water to an adult lung-breathing life on land. In a few cases, e.g. the black salamander (*Salamandra atra*) of the Alps, which lives above the level of water-pools, and some tree-frogs which never come to earth, the aquatic gill-breathing stage is skipped altogether.

In Reptiles, Birds, and Mammals, as every one knows, there is no trace of gills left in early life (though the tell-tale gill-clefts remain in the embryo), and the young are lung-breathers from the time they are born or hatched. A

secondary return to the water is illustrated by some Reptiles —water-snakes, turtles, crocodilians and a single marine lizard (*Amblyrhynchus*); by some birds like the flightless penguins and the pelagic petrels; by some mammals like Cetaceans and Sirenians, seals and sea-lions.

Origin.—Some terrestrial animals probably passed from the freshwaters, through the mediation of marsh and bog. The earthworms form a large cosmopolitan group, now thoroughly terrestrial and indeed avoiding very wet places, but the occurrence of three or four aberrant types (like *Alma* and *Dero*) with gills tells the tale of their historical origin. No one can doubt that the land-leeches were derived from a freshwater stock, for the great majority of leeches (Hirudinea) are tenants of the freshwaters. It is probable that the snails and slugs of dry land originated from a freshwater stock and there is, of course, no dubiety in cases like frogs and toads where the larval life is still spent in the ponds and ditches. The interesting land-crab, *Birgus latro*, which goes far up the mountains and even climbs trees, returns every year to the sea-shore to breed, and its marine larvæ well illustrate the general conclusion that the habitat of the young forms is the ancestral habitat. It is possible that the terrestrial Isopods were also derived from a littoral stock.

If a land-animal has not originated from a freshwater stock or from a littoral stock, how else could it arise? The third mode of origin is from some pre-existing terrestrial stock. Thus Mammals probably evolved from a terrestrial Reptile stock, and Reptiles from a terrestrial Amphibian stock. Thus, again, it is probable that Insects and Spiders sprang from pre-existing terrestrial stocks of Arthropods.

Fundamental Adaptations.—Prof. Cuénot has noted that there are four adaptations essential to thoroughly terrestrial life. (1) The animal must be able to breathe dry air, either by the skin (as in earthworms), or by some special apparatus, such as the air-tubes of insects, the lung-books of scorpions, the pulmonary chamber of snails, and the true lungs of Amphibians, Reptiles, Birds and Mammals. (2) The animal must be able to resist a considerable range of variation in temperature and humidity, and thus we find in terrestrial animals all sorts of cuticular and integumentary structures, such as feathers and hairs, and all sorts of detailed devices for meeting the notable changes in vital conditions that the succession of the seasons involves. Thus hibernation and warm-bloodedness find their place here as exceedingly effective adaptations to terrestrial life. (3) A terrestrial animal will tend to have an abbreviated life-history, or in other words a direct development, for the conditions of life on land are not suited for larval stages. The notable exception is in the case of insects, many of which must be called terrestrial, and many of which have intricate life-histories with a great variety of larvæ. It will be noted, however, that many insect larvæ are very carefully hidden away, that many are specially adapted to be inconspicuous, and that many are peculiarly protected from possible enemies, e.g. by being unpalatable, by being covered with irritating hairs, by exuding repulsive fluids. On the whole, it is safe to say that it is characteristic of terrestrial animals that the young are born or hatched at a very advanced state. What comes out of the egg of a spider or a snail is a miniature of the adult, fully formed. Some species of Peripatus and many insects are viviparous. In

many birds that nest on the ground, the young, known as Præcoces, are able to run about within a short period after hatching; and every one knows how quickly a lamb or a foal gets on to its legs.

In this connexion it is very interesting to notice that in Amphibians which represent the transition-class between aquatic and terrestrial life, there are not a few exceptions in which the larval period, normally passed through in the water, tends to be abbreviated by some peculiar device. Thus the eggs of the South American *Nototrema ovifera* are pushed by the male, after they are laid, into a pocket on the female's back; those of the Chilian *Rhinoderma* are carried by the male in his resonating sacs; those of the Surinam Toad develop in a multitude of little skin-pits on the female's back.

(4) The fourth adaptation is one that might not naturally occur to the non-zoological student. A thorough-going terrestrial animal usually shows internal fertilization of the eggs. In many fishes the eggs are deposited in the water and the fertilizing fluid or milt is deposited upon them or near them. But this is incompatible with the conditions of terrestrial life. There are exceptional cases, it is true, but they tend to prove the rule. Thus one earthworm fertilizes another, but the sperms are extruded again in packets which project as tiny tags on the skin; these spermatophores are included in a barrel of mucus that slips over the earthworm's head and forms the cocoon when the eggs are liberated. What is laid in the ground is a cocoon containing several eggs and numerous sperms.

The terrestrial area has to be divided up into more sub-divisions than any other haunt of life: it is so extraordinarily diverse. We think, for instance, of mountains and islands,

of woods and forests, of moors and meadows, of links and dunes—each with its characteristic fauna and flora. There are peculiar regions like steppes and prairies, tundra and desert, and the circum-polar areas so far as these can be called terrestrial.

Under Ground.—It is interesting to think of the large number of animals that have taken to a subterranean mode of life as burrowers in the ground. There must have been long ago a golden age for the race of earthworms when they discovered the possibility of colonizing a new world below the surface. Ages probably passed before they were followed by the Centipedes who are their inveterate enemies, by some of the burrowing beetles, and by carnivorous slugs (Testacella). Long ages passed before the moles followed the earthworms into the recesses of the soil, and became equally well adapted to the peculiar conditions of that strange mode of life.

Over and over again the same story has been re-enacted, e.g. by burrowing amphibians (Cæcilians), burrowing lizards (Amphisbænids), and burrowing snakes (Typhlops, etc.): a temporary safety has been secured by a change of habitat, and then new enemies and difficulties have been encountered.

Cave Animals.—Caves and grottos have come to be tenanted by a diverse array of animals, more or less adapted to the conditions of life—darkness and constant temperature, absence of green plants, and a humid atmosphere, for thoroughly dry caves have never more than casual tenants. The cave-fauna includes many bats, a few peculiar mice, the Amphibian Proteus of the great caves of Carniola and Dalmatia, and three American salamanders, a good many small fishes, numerous beetles and a few other kinds of

insects, many spiders and crustaceans, various snails, and so on. They tend to be somewhat dwarfed types, with more or less degenerate eyes (except in the bats and mice), with highly developed tactility, and with reduced pigmentation. In those cavernicolous animals in which the development of the eye has been worked out, e.g. Proteus, Amblyopsis (a fish), and Cambarus (a crayfish), it has been shown that the eye of the young form is relatively less degenerate than that of the adult.

Racovitza, who has made a special study of cave-animals, gives an interesting account of an Isopod or wood-louse, Spelæoniscus, from an Algerian cavern. It is colourless, blind, and covered with tactile setæ; it has no longer any near relatives living in the light of day; it is an archaic representative of a fauna which has disappeared. It was in a sense a failure, Racovitza thinks, for whereas it can roll itself up in a ball like many other Isopods, such as the widely distributed *Armadillidium vulgare*, its antennæ are left sticking out and exposed to danger. So it had to become a Troglodyte. Racovitza suggests that it is not the only failure who has taken refuge in a cave, 'cet asile que dame nature installa à peu de frais pour ses veillards, ses impotents et ses ratés'.

VI. The Aerial Fauna

The last haunt of life to be tenanted was the air, and it is interesting to notice how many attempts have been made to possess it. Among backboneless animals the insects alone have attained to the power of true flight, but among backboned animals there are three instances of success—the extinct Pterodactyls, the Flying Birds, and the Bats. Thus in each of the three great classes of air-

breathing Vertebrates—Reptiles, Birds and Mammals—the problem of flight has been solved, each time in a different way.

The power of taking 'soaring' leaps has been acquired many times over in the history of Vertebrates. R. S. Lull gives ten cases—*Rhacophorus*, *Ptychozoon* (a lizard with a long fringed tail), *Draco* (a lizard with the skin extended on greatly prolonged ribs), and seven Mammals, *Petauroides*, *Petaurus*, *Aerobates*, *Anomalurus*, *Pteromys*, *Galeopithecus* and *Propithecus*. Except in *Petauroides*, there is in these swooping mammals a fold of skin along the animal's flanks, which may be supplemented by folds in front of the fore-limbs, between the hind limbs, or along the tail. In the much-debated movements of the Flying Fishes (Thoracopterus, Gigantopterus, Exocoetus, and Dactylopterus), there is at most an approximation to true flight.

It is not surprising that many of the attempts to possess the air should have proved quite unsuccessful, for man's own experience of aviation has taught him that success depends on numerous fine adjustments, and is not to be attained except at great cost of life. In the case of birds there is a remarkable correlation of numerous adaptations —the somewhat boat-like shape of the body, the ballasting of the body with heavy organs below, the lightly built skeleton with bones of the hollow girder type, the arrangement by which the flying helps the breathing, the enormous development of the pectoral muscles sometimes attaining to half the whole weight of the bird, the turning of an arm into a wing, the possession of feathers with inter-linked barbs, the fusion of dorsal vertebræ to form a steady basis against which the wings can work, and so on through a long list.

From the evolutionist point of view it is interesting to notice that in Bird, Bat and Pterodactyl the flying organ is in each case the arm, and yet the details of the transformation are very different in the three cases. With precisely the same fundamental material to work with, three entirely different types of wing have been evolved.

In insects the wings appear to be entirely novel structures—hollow, flattened sacs growing out from the upper parts of the two posterior divisions of the thorax; but it is possible that they were, to begin with, rather respiratory than locomotor organs. Indeed, in some cases they still have considerable respiratory function—containing blood-channels and extensions of the air-tubes or tracheæ. As illustrations of analogy it is interesting to compare Birds and Insects, for they are as far apart from one another anatomically as they could well be, and yet they have much in common—lightly built bodies, highly specialized musculature, very elaborate respiratory system with active expiratory movements, and so on. These are convergent adaptations towards the same end in entirely different types.

It is probable that the Vertebrate animals which have attained to the power of true flight have sprung from *arboreal* stocks. It is likely that the oldest known bird —the extinct Archæopteryx—which had teeth on both jaws, a long lizard-like tail, and claws on each of the three digits of the half-made wing, was definitely arboreal. The same conclusion is suggested by the Hoatzin (*Opistho comus*), one of the most primitive of living birds, whose young ones clamber about on the branches. It is probable that the Bats sprang from a stock of arboreal Insectivores.

Most of the insects which are aerial as adults spend the

early part of their life on the ground, or on herbs and bushes, or in the water, for the possession of the air is, of course, a secondary victory. It is interesting to notice, however, how very independent of the earth many of the birds have become, with even their nests far off the ground. How thoroughly aerial a bird may be is well illustrated by the common swift, which throughout the long summer daylight never alights or pauses, except for brief moments at the nest.

Gossamer.—In illustration of successful adventure into the air, the flights of gossamer-spiders may be noticed. At various times throughout the year, but especially in the autumn, large numbers of small spiders congregate on the tops of palings and bridge-rails and herbage, and standing on tiptoe with their head to the breeze, allow long threads of silk to pass from their spinnerets. When the parachute is long enough and the wind begins to pull on it, the spiders let go their hold of their support, and are borne on the wings of the wind from one parish to another. If the wind should fall, the spiders can 'spread more sail' by lengthening their silken threads. If the wind should rise, the spider can 'furl their sails' by winding in part of their parachute. When tens of thousands of small spiders migrate simultaneously some fine morning, there may be, as they sink to earth, a shower of gossamer, covering the fields for acres. In many cases we see and feel threads of gossamer floating in the air without any attached spiders; these are usually broken-off parts of parachutes. They recall to us the failures of the days before achievement.

CHAPTER III

THE INSURGENCE OF LIFE

(The Circumvention of Space and the Conquest of Time)

'She is the only artist; working-up the most uniform material into utter opposites; arriving, without a trace of effort, at perfection, at the most exact precision, though always veiled under a certain softness. . . .'

'She is all things. . . . She is rough and tender, lovely and hateful, powerless and omnipotent. . . .'

'She is cunning, but for good ends; and it is best not to notice her tricks. . . .'

'The one thing she seems to aim at is Individuality; yet she cares nothing for individuals. She is always building up and destroying; but her workshop is inaccessible.'

—*Goethe's Aphorisms*, translated by Huxley.

Productivity—Filling every niche—Difficult Conditions—Tenacity of Life—Plasticity—The Biology of the Seasons—Migration as an Instance of Insurgence.

IN many of its familiar expressions life seems to be an extraordinarily delicate form of activity—easily disturbed and spoilt and ended. A little quickening of the rate of metabolism, and life's fitful fever is over. A slight lack of harmony in the internal laboratory, and the happy child becomes a cretin. A pin-prick below the thumb-nail when he was planting seedlings and the robust gardener dies of lockjaw. An unusually cold night and two

hundred birds are gathered in the morning in one stackyard. This does not sound much like the insurgence of life!

It must be pointed out, however, that the impression we often get of the brittleness of living creatures is apt to be fallacious. Truly the more intricate of them have exquisitely balanced organizations, with machinery that is easily put out of gear, for the more parts there are, the greater is the likelihood of something going wrong, and chemical complexity often involves chemical instability. But the big fact is that life is *tough*.

A boy whirling a stick, a pigeon strutting on the ground, a fortuitous contact between boy's stick and pigeon's skull, and it is all over with the favourite bird. This is a trivial instance of what in the course of life we have far too many occasions to deplore, namely *casualties*. Socially, a casualty means an accident for which no one in particular is to blame; it is put down to 'the hand of God'. Biologically expressed, a casualty is a fortuitous and fatal incidence, on a living creature, of forces to which it cannot in any effective way respond. It is plain enough that if the pigeon had only had the skull of an elephant, or a ram for that matter, it would not have died from a slight 'concussion of the brain' induced by the schoolboy's carelessly-handled stick. But then it would not have been a pigeon, and could not have been a pigeon, for the real answer to the apparent difficulty is that complex organisms cannot be adapted to casual dangers, that they would be unthinkably handicapped if they were. Therefore, when we think of the terrible destruction in the fauna of the Gulf of Naples after an eruption of Vesuvius, or the decimation both on the shore and inland that follows an unusually hard winter, we are forced to admit that we cannot expect

organisms to be adapted to resist other than normal conditions. Our expectations are often, however, agreeably disappointed.

We admit, then, that organisms are often tender plants, frail edifices, delicate pieces of vital machinery, adapted for a relatively constant, or at any rate regular environment, and not for casualties. But the much bigger fact is the toughness of life, which we wish to illustrate in this chapter. It is difficult to get a fitting word for the quality that impresses us all—the self-assertiveness of life, its power of persistence against difficulties, its habit of attempting the apparently impossible and leading forlorn hopes. We have called it the *insurgence* of life.

Perhaps the primary illustration of the quality is to be found in the fundamental fact about life, that although the organism is always changing, it yet remains approximately the same. It is always burning away, but it is not consumed. It is continually arising like a Phœnix from its own combustion. Ceaseless metabolism in all ordinary cases, and yet a retention of integrity or intactness—that is the fundamental wonder of life. To this we shall have to return in our final chapter.

Productivity

In illustration of what we venture to call the insurgence of life, we may begin by recalling a few instances of productivity. Life is like a stream that is continually tending to overflow its banks. A little one is always becoming a thousand, and a small one a great nation. Some of us on an ocean voyage may have watched the sun set in the water, lingering for a minute or two like a ball of fire balanced on the tight string of the horizon, and may have

waited till it became quite dark except for the stars and the steamer lights, and then enjoyed the splendour of oceanic 'phosphorescence'. There is a cascade of sparks at the prow, a stream of sparks all along the water level, a welter of sparks in the wake, and even where the waves break there is fire. So it goes on for miles and hours—a luminescence due to the rapid vital combustion of pinhead-like creatures (Noctiluca and others), so numerous that a bucketful contains more of them than there are people in London. We are filled with amazement at the prodigal abundance of life.

Taking the slowest breeder among mammals, Darwin calculated that a pair of elephants, living for over a century and rearing one offspring every ten years, would have in 750 years, barring accidents, nineteen millions of descendants. Wallace quotes Kerner's statement that a common weed, *Sisymbrium sophia*, often has three-quarters of a million of seeds, and that if these all grew to maturity and seeded, the whole of the land-surface of the globe would be covered with the result within three years.

The very general absence of parental care of any sort among fishes is a familiar fact, partly explicable because fishes are creatures of low degree in the Vertebrate alliance, and partly because of the prolific reproduction. With egg-laying in the open water in the great majority of cases, parental care would be difficult, and survival is secured by great reproductivity. It is sometimes extraordinary. A ling weighing 54 pounds had 28,000,000 eggs, a turbot of 17 pounds 9,000,000 eggs, a cod of 21½ pounds 6,000,000 eggs. In four herrings the number of eggs varied from 20,000 to 47,000.

In many of the less differentiated animals there is not

only great fertility, but rapid coming to maturity. Mr. Newton Miller has supplied precise data as to the fertility of the brown rat in captivity, and these are of serious human interest because of the importance of this animal as a destroyer of food-supplies and a disseminator of disease. The creature breeds all the year round, and five or six litters may be actually reared by a pair in the course of a year. If the young are destroyed or removed at birth, there may probably be a litter every month. In one case seven litters were produced in seven months by one female. The young are carried from 23½–25½ days before birth. The number in a litter varies from six to nineteen, with an average between ten and eleven. They are not full grown before eighteen months, but both sexes are ready for reproduction not later than the end of the fourth month.

The rabbit may have six young ones in a litter, and four litters in a year; and the young may begin to breed when they are six months old. This rate is far surpassed by some of the mice, and when we descend to the level of insects and the like we find an extraordinarily rapid succession of generations. In the time required for the production of one generation of a larger higher animal, the lower type has had many generations and has produced an enormously greater weight of living matter. It was this that led Linnæus to say that three flies consume the carcass of a horse as quickly as a lion ('Tres muscæ consumunt cadaver equi, æque cito ac leo').

Huxley calculated that if the descendants of a single green-fly all survived and multiplied, they would at the end of one summer weigh down the population of China. The descendants of a common house-fly would in the same time —six generations of about three weeks each—occupy a

space of something like a quarter of a million cubic feet, allowing 200,000 flies to a cubic foot. An oyster may have sixty million eggs, and the average American yield is sixteen millions. If all the progeny of one oyster survived and multiplied, and so on till there were great-great-grandchildren, these would number sixty-six with thirty-three noughts after it, and the heap of shells would be eight times the size of the earth! Of course none of these things happen, because of the checks imposed by the struggle for existence. Yet every now and then, as man knows to his cost, a removal or diminution of the natural checks allows the potential productivity to assert itself for a short time or within a limited area. The river of life sometimes does overflow its banks, as it always *tends* to do, and the resulting flood is called a plague. But one plague brings another in its train, as in Egypt long ago, and things right themselves, usually with considerable loss in the process.

The large African land-snail *Achatina fulica* was introduced about 1900 into central Ceylon, but was shortly afterwards practically exterminated. A couple that escaped destruction were carried down some years afterwards to the low country. 'Here they increased to such an amazing extent, over an area of about five square miles, that their numbers were to be reckoned by millions, no fewer than 227 being counted in a cluster on the stem of a cocoa-nut palm in a length of about 6 feet'. Luckily little or no damage has been done, as the snail acts as a scavenger. The adults are attacked by a terrapin of the genus Nicoria, the young stages have many enemies, and the early exuberance of multiplication is now being checked.

On the night before the new or full moon in the middle or latter half of December there occurs the remarkable

swarming of the Japanese Palolo worm. It invariably takes place about midnight just after flood-tide. At 1 a.m., Akira Izuka relates, the worms 'covered the whole water as with a sheet' and were thick down to a depth of a fathom. By 2.15 a.m. there was not a single worm to be seen; the reproductive orgasm was over. The phenomenon appears to us to be a dramatic instance of the abundance of life, of the crisis-nature of reproduction, and of the precise way in which internal rhythms may be related to external periodicities.

Dr. Th. Mortensen has called attention to the extraordinary fecundity of the starfish *Luidia ciliaris*, which is well known in British seas. The beautiful red ovaries are arranged in a double series in each arm or ray—300 in an arm 30 cm. long. As the species is seven-armed a complete female of that size, which is nearly the average, has 2,100 ovaries. In one ovary there are at least 300,000 eggs, probably nearer half a million. As the ovaries are smaller towards the tip of the arm, it may be just to take the mean number of eggs per ovary at 100,000, and the number of ovaries may be reduced to 2,000; this gives the number of eggs in a grown female at no less than 200 millions. Yet the larvæ are relatively rare and the adults are far from common. 'What a waste of eggs must here take place!'

Professor Lorande Loss Woodruff, of Yale, who has devoted many years to the experimental study of the slipper animalcule (*Paramœcium*), gives a very interesting account of a five-year pedigreed race. On May 1, 1907, he started with a 'wild' *Paramœcium aurelia*, isolated from an aquarium. When it had produced four individuals by division, these were isolated to form the ancestors of

four lines. The pedigreed culture was maintained by taking a specimen practically every day from each of these lines up to May 1, 1912. This facilitated an accurate record of the number of generations attained, and it also precluded the possibility of conjugation taking place, for this process of incipient sexual union does not occur between forms which are all descended from one by repeated asexual fission.

In the five years there were three thousand and twenty-nine generations, four hundred and fifty-two in the first, six hundred and ninety in the second, six hundred and thirteen in the third, six hundred and twelve in the fourth, and six hundred and sixty-two in the fifth. The mean rate of division was over three divisions in forty-eight hours.

The slipper-animalcules were as healthy in 1912 as in 1907. They had given evidence of the potentiality of producing a volume of protoplasm approximately equal to 10,000 times the volume of the earth! The experiments illustrate admirably the extraordinary self-reproducing capacity of living matter. They also seem to show that given an ideally favourable environment there is no need for the occurrence of conjugation and no reason for senescence. The slipper-animalcules preserve the secret of eternal youth.

Filling every Niche

Fauna of a Stone.—No one who has made the experiment will forget the lesson learned by making a census of the population of a single creviced stone brought up by the dredge. Molluscs, Crustaceans, Worms, Echinoderms, Zoophytes, Sponges, Protozoa, and other groups may be

all represented. In a report on the Bryozoa collected on the Clare Island Survey, Mr. A. R. Nicholls notices that from one stone no fewer than fourteen different species of these colonial 'moss-animals' were obtained. A small stone bore eleven species of the same class! We see the same filling of every corner all the world over.

Red Snow.—The striking phenomenon of Red Snow was known to the ancients and is mentioned by Aristotle. It occurs all the world over and affords a good illustration of what we call insurgence. It seems to be most abundant in the Far North and Sir John Ross described the 'Crimson Cliffs' of Greenland as extending for miles! The ordinary 'red snow' is due to swarms of a Flagellate Infusorian, *Sphærella* (or *Protococcus*) *nivalis*, sometimes claimed by the botanists, but there are sometimes red animals of higher degree, namely Rotifers, Water-Bears, Mites, associated with it—forming a 'Red Snow' fauna. The facts have been recently summed up by Mr. James Murray, who was zoologist on Sir Ernest Shackleton's Antarctic Expedition. He found abundance of a red Rotifer, which he named *Philodina gregaria*, forming conspicuous blood-red stains on stones at the margins of lakes, and increasing with prodigious rapidity. It lives frozen in ice for years, and resumes activity whenever the ice melts. Vogt found a related species (*Philodina roseola*) on the Alps along with the Flagellate 'red snow'; Langerheim found the same association in Ecuador. The red colour of both Alpine and Polar Rotifers is confined to the stomach, which looks as if the colour were due to the Rotifers making meals of the Flagellates. Mr. Murray notices in addition that M. Gain of the Charcot Antarctic Expedition found red mites along with the red snow, and that Ehrenberg long ago

found a red water-bear and a red Rotifer (*Callidina scarlatina*) among snow on Monte Rosa at a height of 11,138 feet, which is another good instance of the insurgence of life.

Brine Shrimps.—The pretty little brine-shrimp (*Artemia salina*) that used to occur in British salterns, and has a widespread distribution from the Great Salt Lake of Utah to Central Asia, is famous in several ways, and notably because it can live in water with as much as 27 per cent. of dissolved salts, yet occurs, though rarely, in fresh water. It is usually about half an inch long and has a pale reddish colour, due, as Sir Ray Lankester first showed, to the presence in the body fluids of hæmoglobin—the characteristic vertebrate blood pigment which is somewhat rare in Invertebrates. In some places the colonies seem to be altogether female, and parthenogenesis obtains, the eggs developing without being fertilized. In other localities males are common and reproduction takes place by means of fertilized eggs. Sometimes the Brine Shrimp is viviparous, the eggs hatching within the mother's brood-sac and giving rise to microscopic larvæ (Nauplii) with three pairs of limbs and an unpaired eye. Variable in its reproduction, the Brine-Shrimp is variable also in its form, especially as regards the end-lobes of the tail and the bristles they bear. Perhaps this is correlated with the chemical diversity of the habitats frequented. The eggs can survive being dried and may be blown about by the wind or carried on the feet of birds from one salt pond to another. We have already referred to their occurrence in Tidman's Sea-Salt.

A Hazardous Home.—One knows the narrow shelves high up on the Alps, which, for part of the year at least, are the homes of men, women, and children; one knows the narrow ledges on the precipitous Bird-bergs where

kittiwakes and guillemots and many other sea-birds have their summer quarters and bring up their family; one has seen the water-snails browsing nonchalantly on the minute vegetation on the stones of the Niagara River within a few yards of the Falls; but are any of these habitats so remarkable as that of a spider that lives inside one of the Pitcher-plants? In that notorious lure for insects, with its very slippery internal surface, and noxious dungeon full of rottenness, the spider lives and thrives. Forestalling the plant, it catches some of the insect victims as they slip down the *facilis descensus Averni* and sucks their juices, letting the dry corpses tumble into the pit. This is certainly one of the strangest of habitats. They say, moreover, that when an insectivorous bird—aware of the plant's device—arrives on the scene and proceeds to break down the prison-walls, the spider plunges into the foul fluid in the foot of the pitcher, is able to survive suffocation for a time, and eventually escapes as the tearing-up is accomplished.

Larvæ of Flies.—There is no parallel in the rest of the animal kingdom to the variety of habit and habitat that is illustrated by the larvæ of Dipterous insects. Mr. J. C. Hamon found larval Stratiomyidæ in a hot spring in Wyoming, where he could not keep his hand immersed, and others occur in brine. Some are found in the rushing torrent, and others in the rain-water barrel. Some are found in the midst of filth, and others cannot endure the least contamination. Some are parasitic, and others have an extremely active free life. Let us take as an instance in more detail the larva of *Simulium reptans*, a British representative of the buffalo-gnats. The adult fly bites hard and is irritating to man, but it is not to be compared

with other species which do serious damage among herds of cattle in the valley of the Danube and in the United States.

The larva of *Simulium reptans* lives in rushing water, holding on to water-buttercup and the like by a clawed sucker at the posterior end of the body. It has a similar sucker on the thorax, and it seems to use this one when it moves about on the weed. Another safeguard is to be found in its ability to exude an attaching thread from its salivary glands. It is about 12 mm. long, of a greenish-black colour, and it is continually wafting food into its mouth by the action of two pairs of beautiful sweepers. The larva pupates in a silken pouch or cocoon fixed to the weed, and showing a pair of projecting respiratory processes. Professor Miall describes the emergence of the winged fly from the sub-aquatic cradle, and how it is wafted up to its appropriate element as if inside a large water-bubble —an ingeniously simple device!

Nets of Caddis Larvæ.—C. Wesenberg-Lund has given a very interesting account of the peculiar nets made by the larvæ of some of the Caddis-flies of lakes and streams. They serve for the capture of the drifting plankton. Some are trumpet-shaped, up to four inches in length, with the mouth always upstream. They are bluish-green in summer because of the Algæ on the threads, and brownish in winter because of the diatoms. Other nets are flat, with an aperture in the centre leading down into a tunnel beneath a stone; others are like swallows' nests and are fastened in large numbers to the vertical banks; others are funnel-shaped and fixed to the pond-weed leaves; others make chains of baskets out of duck weed leaves and spin a web on the front of each. The

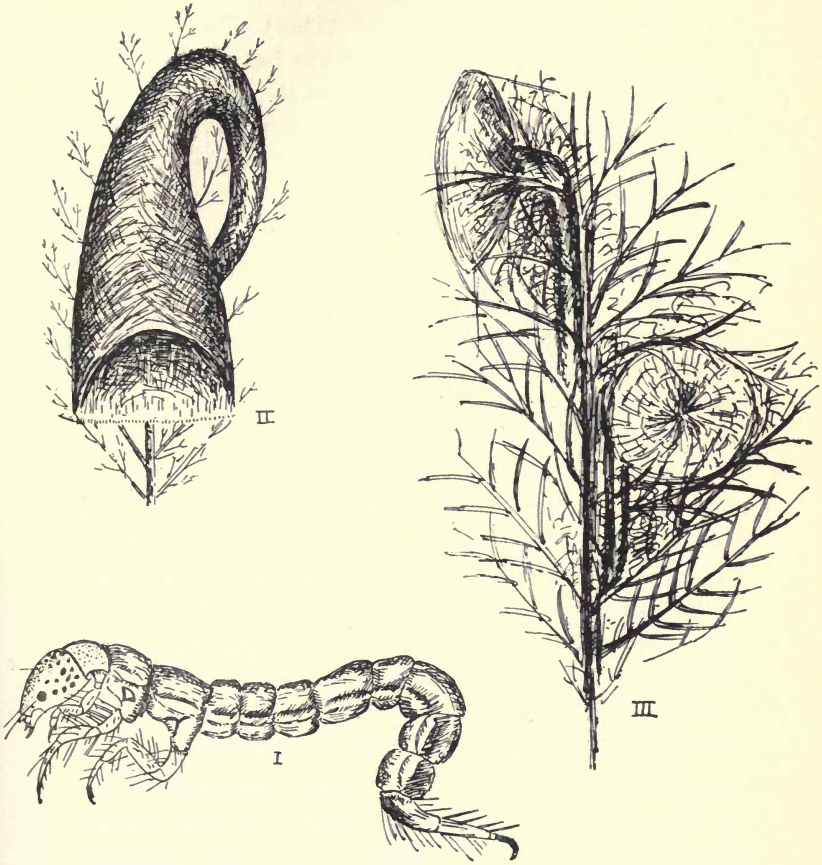
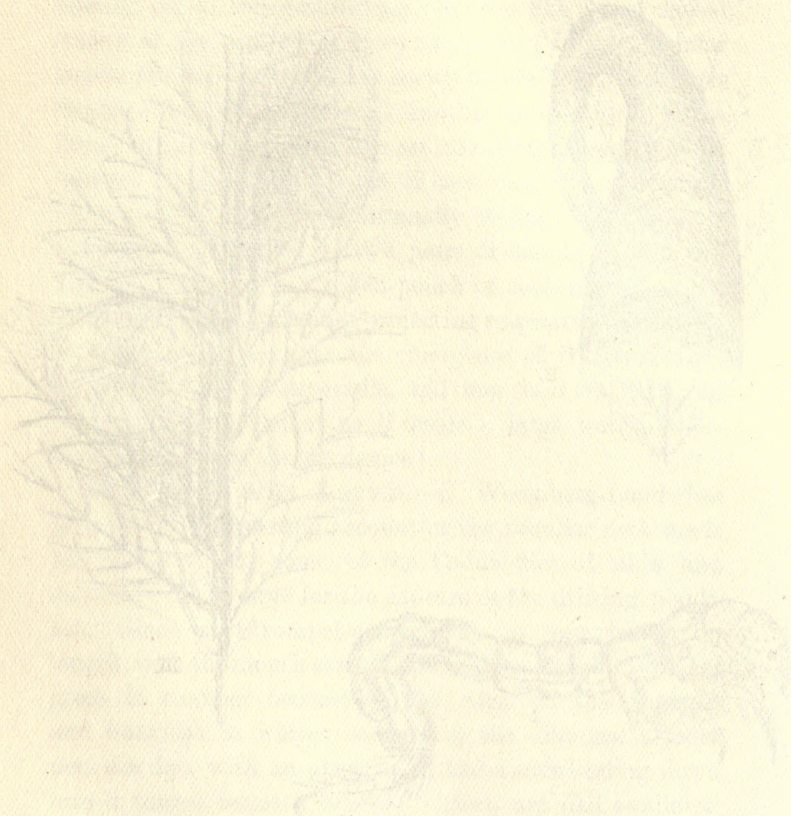


FIG. 36.—Nets of larval Caddis-Flies. (*After* Wesenberg-Lund.) I. Larva of Holocentropus dubius. III. Its snare-nest. II. Snare-nest of Neureclipsis bimaculata.



spinning larvæ are campodeiform in type, that is, not so worm-like as ordinary caddis-worms, and they differ also in being very sedentary and practically carnivorous. The author writes (in 1911): 'It seems strange that until now we have hardly had any idea at all as to the spinning powers of these animals; as the spider spins its web above ground, and lies in wait for the winged insects and the flying plankton of the air, so the campodeoid larva constructs its net, lurking for the small animals and floating plankton of lakes and water-courses.'

Strange Habitats.—In hunting for earthworms one does not naturally look up a tree, but Dr. Robert Stäger has shown that it is a useful plan to search in unlikely places. In exploring on the Alps he investigated the mossy cushions which often flourish on the stem and branches of the sycamore and bear ferns and various flowering plants. In that strange habitat he found four different species of earthworm. Others occurred in the familiar cushions formed on almost bare rock by plants like *Dryas octopetala*, *Silene acaulis*, and *Gypsophila repens*. Again we have illustration of the way life insinuates itself into every vacant niche.

Another strange habitat is that of an 'unsalamander-like salamander' (*Autodax lugubris*) which lives up trees (*Quercus agrifolia*). W. E. Ritter found them in holes at a height of 30 feet, sometimes as many as a dozen in one hole, representing perhaps a family. Most of the cavities occupied had very narrow openings. The eggs are hung in clusters from an overhanging surface, each egg on a little string of its own, and both sexes look after them. Most Amphibians are gentle creatures, but these Salamanders are very ready to show fight in defence of their eggs or themselves, and they have very large teeth.

Another series of strange habitats has been found in the burrows made by moles and hamsters and other mammals of similar habit. There are, of course, accidental co-tenants; and there are others which though often found in burrows occur elsewhere as well; and there are parasites belonging to the burrowing mammals. But after these are taken account of there remains a distinct burrow-fauna, just as there is a distinct cavern-fauna. Thus L. Falcoz mentions the Staphylinid beetles, *Heterops prœvia*, *Oxypoda longipes*, and *Aleochara spadicea* as good illustrations of the fauna of moles' nests.

Many beetles visit nests casually for pickings; others are frequenters of nests but of other suitable places as well; there is a third lot of exclusively 'nidicolous' Coleoptera, and the list of these drawn up by Bickhardt in 1911 came to twenty-eight. Eighteen of these are confined to the homes of mammals, such as mole, hamster, mouse, and rabbit; seven are confined to the nests of birds, such as dove, sand-martin, owl, and woodpecker; three are found associated with both birds and mammals.

A curious refuge is that of the rare sea-otter—on the great beds of kelp seaweed (*Macrocystis*) which fringe the rocky coast of the North Pacific, among the Aleutian and Kurile Islands. We read that 'these great kelp beds make calm water, though the surf be roaring and breaking just outside, and are dense enough for the otters to lie upon.' In the middle of the nineteenth century the sea-otter was still comparatively plentiful all round the North Pacific coast, now it is hardly to be seen even by the exploring naturalist. It is interesting in its adaptations for aquatic life—the hind feet being suited only for swimming; in the adaptation of its back teeth for crunching crabs,

molluscs, and sea-urchins—the crowns being smooth and rounded; and in the care for the pup which the mother shows,—dandling it, and diving with it.

The Penelope Spider.—Not only do living creatures fill every cranny in the rock-pool, every nook in the grassy bank, they take advantage of every niche of opportunity. The illustrations are world-wide. Professor Goeldi gives us one from a garden near Parà. The time is long before dawn and the chief actor is a spider, spinning in the dim light. Before the sun rises her web is finished, and it serves to catch the winged male scale-insects in their early morning flutter. But as the sun rises, the spinner grows restless; she dislikes the light of day, just as does the poacher who has by night spread in the field his net for birds. So, at the dawning, the spider draws her net together with its quivering delicate captives, and retires into the shade to investigate the catch. It was only by staying up all night in the garden that Professor Goeldi's son discovered the secret of this light-avoiding spider whose web disappears with the morning dew. It is a mode of bread-winning that fills a curious niche of opportunity. Penelope-like, the spinner makes and unmakes her web each day, but not without effective results to man (by destroying the injurious scale-insects) as well as to herself.

Successive Waves of Life.—The pressing insurgence of life which is illustrated by the way in which organisms fill every niche—even the least inviting—is illustrated in quite another way when we observe a sequence of possessors passing like waves over a particular environment. When one horde has made an area uninhabitable for itself by exhausting the food-supply, there may come another able to cut even closer to the bone. We see this in a very

striking way in the sequence of animal and plant life in a 'hay infusion'—one form after another rising into dominance and then disappearing. In this connexion Professor L. L. Woodruff of Yale has shown that the slipper-animalcule (*Paramœcium*), excretes substances which are poisonous to itself when they accumulate in a limited environment. Thus when *Paramœcium* reaches its maximum, the beginning of the end is not far off.

Difficult Conditions

Who has not been impressed by the way in which living creatures triumph over the most unpromising circumstances? We went up the other day to a well-known minor pass in the Alps where we were getting near the lasting snows and the bare inhospitable rocks. It seemed ill-suited to be a home, but what impressed us most, after the view of the mountains, was the abundant insurgent life; we felt what Bergson calls the *élan*, the spring, the impetus that is characteristic of life. Not only were there many beautiful flowers coming up even at the thinned edges of the snow mantle, but there was quite a rich insect life. Conspicuous, too, were the large, white-bellied Alpine swifts, perhaps the most rapid of birds, continually swirling about, all in silence, in the cold air: emblems of insurgent life. Shy marmots whistled from among the rocks. Flocks of white moths floated up in the mist, rising like the souls of animals that had died far below. We felt the insurgent indomitable quality of life.

Antarctic Shores.—On Sir Ernest Shackleton's Antarctic Expedition several collections were made at Cape Royds (77° 32′ S.), at first sight a most unpromising locality. On the shore there was no vestige of life; nothing but

funereal black sand when the ' foot-ice ' was gone. Inshore there was black lava, showing no vegetation higher than mosses, and very little of them. Even the lichenous *tripe de roche*, familiar in books of Arctic exploration for its rôle in staving off starvation, was scarcely so abundant as to fulfil the same life-saving rôle in the Antarctic. Ice covered the sea ; ice—fifteen feet of it—covered the little lakes. Could any faunistic outlook have been more unprepossessing ?

But the reality was very different from the appearance. Mr. James Murray and the other workers under his guidance wasted no time in bemoaning the absence of faunistic amenities. They made holes in the ice, which the Weddell seals helped to keep open, and set traps which yielded molluscs, crustaceans, and worms. They managed to haul a dredge from one hole to another, and got sponges, sea-anemones, alcyonarians, starfishes, crustaceans, and molluscs. They cut down through fifteen feet of ice in the small inland lakes, and reached a floor of ' foliaceous vegetation ',—and a rich micro-fauna and micro-flora. There were abundant Rotifers, especially of two new viviparous species, which subsequent experiment showed to be able to withstand all sorts of changes of temperature. There were ' water-bears,' or Tardigrades, and water-mites, and two species of ' water-fleas ', besides thread-worms, Infusorians, and two kinds of Rhizopods. Here then in the collecting at Cape Royds we get another illustration of the insurgence of life. We see life persistent and intrusive—spreading everywhere, insinuating itself, adapting itself ; resisting everything, defying everything, surviving everything.

Desert-Plants.—A well-known adaptation to difficult

conditions is exhibited by desert plants which store water. They have a relatively large root-system which enables them to make the most of any available supply. F. V. Coville found in the Mohave Desert, California, a branching cactus (*Opuntia echinocarpa*), 19 inches high, which had a network of roots extending over an area 18 feet in diameter. These roots were 2 to 4 inches below the surface, suited therefore for utilizing a downpour. Some desert plants send their roots deep, and Professor R. H. Forbes has described an acacia of Arizona which has a double root-system, one for absorption near the surface, and the other for searching deeply.

The collecting surface is great, and the losing green surface is small; the whole plant, as in many cactuses, may be like a ball or barrel and without leaves. The structure of the cuticle and even of the transpiration pores is adapted to lose as little as possible, and the interior of the plant consists chiefly of water-storage cells, so that as much as 96 per cent. of water can be collected. The plant becomes a tank and the water is often quite drinkable. A Barrel-Cactus or Bisnago (*Echinocactus emoryi*) studied by Coville yielded 3 quarts of water from about 8 inches of a plant about a yard high and 20 inches in diameter. It may be further noted that the Bisnago is effectively protected against grazing animals by the impenetrable armour of hooked and rigid spines, and another notable feature is the fluted surface which allows it to expand and contract without cracking. When we think of the root-system, the leaflessness, the barrel-shape, the skin, the water-cells, the spines, the fluting—we realize what a bundle of adaptations this desert plant is, and many other slightly different examples might be given. Although the Barrel-Cactus

seems to be peculiarly safe (except from man, who sometimes taps it), there are many desert plants whose stores form the only water supply of not a few of the desert animals.

Rock-Borers.—Life's characteristic filling of every niche leads to extraordinary modes of life. Instead of seeking a life of ease, many animals attempt what seems impossible, and achieve it. Take the simple case of boring bivalves, like the Pholads, which work their way into hard rock. According to one theory, the boring is at least partly due to an acid secretion; according to another view it is mainly accomplished by mechanical means. Miss B. Lindsay made a very careful study of *Zirphæa* (*Pholas*) *crispata* and *Saxicava rugosa* at St. Andrews, and came to the conclusion that the boring is in these cases entirely mechanical. The Pholas works in two ways—sucking and scraping. 'It might be described as a combination of a nutmeg-grater and a vacuum-cleaner'. The foot is extruded; a wide gap appears between the foot and the mantle; the mantle becomes fully extruded, and then rotatory movements begin. An interesting detail is that the shells consist of aragonite, which is harder than the usual calcite, and this must help a little in the process of boring, which remains, however, when all is said, a very remarkable performance.

Climbing Fishes.—There is a well-known tropical fish, Periophthalmus, which, like its relative Boleophthalmus, spends hour after hour out of water, squatting on the mud by the sides of the estuaries, or even climbing up on the roots of the mangrove trees. But such climbing powers as Periophthalmus possesses are far surpassed by those of a catfish, *Arges marmoratus*, which lives in the torrential

rivers of the Andes, where there is a rapid succession of falls, cascades, and potholes. Under usual conditions Arges is a clumsy and awkward swimmer, but for creeping and climbing in the torrents it is wonderfully adapted. It anchors itself by its suctorial mouth, and works itself upstream with the help of a ventral bony plate bearing the ventral fins and equipped with strong muscles which move it backwards and forwards. The plate is studded with small sharp teeth pointing backwards. These catfishes climb up the smooth water-worn surfaces of deep potholes, and have been known to ascend eighteen feet without a slip or fall.

Terrestrial Animals Under Water.—On the Mediterranean shore among the calcareous Algæ, Racovitza found a marine spider, which Louis Fage has described under the title *Desidiopsis racovitzai*. It lives in crevices, in burrows (of *Lithodomus*), in empty shells (of *Vermetus*), and keeps the water out more or less by spinning threads across the entrance to its retreat. There is no tide to contend with, but it is a strange abode for a terrestrial animal. Unlike the freshwater spider, it cannot swim. It can remain for a long time under water, but has to return to dry land periodically to get a supply of air, which is entangled about the posterior body. What the creature feeds on is uncertain.

A species of mite, *Erythræus passerinii*, belonging to a terrestrial stock, is known to live in the crevices of the sea-shore rocks, and to be able to withstand prolonged immersion. It utilizes the air imprisoned in the capillary passages in the cracks of the rocks. A primitive wingless insect, *Anurida maritima*, which has been carefully studied by Imms, lives habitually among the sea-shore rocks. When

the tide rises it retreats far into crevices or into the sand. The whitish hairs on its body hold a supply of air, which may last for 4½ days. There are also two British parasitic gall-flies that occur at high-water mark among the sea-weed of the jetsam.

Aquatic Insects.—The adaptations of aquatic insects form a well-nigh inexhaustible theme. Let us take a couple of instances from Dr. Böring's account of the larvæ of the Donaciinæ, a sub-family of the Chrysomelids, or leaf-beetles. The larvæ puncture the roots of water-plants, such as pond-weed and Sparganum, and feed on the exuding sap. In making the hole, by means of the cutting mandibles, the neatest possible contrivance comes into operation. The first segment of the thorax slips forward against the plant and within the water-tight compartment thus formed, the head works freely and the sap is kept from adulteration with water and debris.

The adaptation for breathing is not less striking, for the larvæ manage to tap the stores of air in the intercellular spaces of water plants. A hooked breathing pore or spiracle at the end of the abdomen is plunged into the tissue of the plant and the air finds its way (in a somewhat intricate fashion) into the breathing-tubes or tracheæ of the insect. Similarly, after the larva has enveloped itself in a secreted cocoon, it actually bites a hole, or more than one, at the bottom and establishes connexion with the air spaces of the root to which it is attached. In this way it secures a supply of air during its pupal period!

Against the Grain.—It seems to be part of the Amphibian constitution to have an antipathy to salt—a small quantity being often fatal. Referring to the absence of Amphibians from strictly oceanic islands Darwin pointed

out that they throve particularly well when artificially introduced, as into Madeira, the Azores, and Mauritius, 'but as these animals and their spawn are immediately killed (with the exception, as far as known, of one Indian species) by sea-water, there would be great difficulty in their transportal across the sea, and therefore we can see why they do not exist on strictly oceanic islands'. They could not be transported on trees and the like, as some animals have been, without fatal drenching. Darwin makes mention of an exception, and we have recently (1911) had a circumstantial account by Mr. A. S. Pearse of sea-shore frogs at Manila. He quotes Dr. Gadow's words, 'Common salt is poison to the Amphibia; even a solution of 1 per cent. prevents the development of the larvæ', and then reports that he saw little frogs of the genus Rana hopping about on the flats of an *estero*, or tidal creek, opening into Manila Bay. Two holes made by the crab *Sesarma bidens* were seen to be full of wriggling tadpoles newly hatched. Samples of water from a pool with tadpoles on the edge of the creek were analysed, and it was found that the tadpoles were developing in slightly diluted sea-water, containing as much as 2 per cent. of sodium chloride. It seems, then, that both tadpoles and frogs can stand much more than a grain of salt.

Audacity.—There is sometimes what we may venture to call sheer *audacity* in the things animals do and succeed in doing. Taking such a serious matter as the disposal of the eggs in birds, we find, of course, all manner of careful nests and secure hiding-places and safe sites, but we also find sheer audacity. We do not refer to the often reported cases of birds nesting inside a hat, or up the sleeve of a coat, or inside an unlit station-lamp; for while a few of

these are interesting, the majority are not, since we are apt to forget that the bird does not know what hats and sleeves and lamps are. In many cases, moreover, these divergences prove dismal failures. We refer rather to cases like the nesting of the White Tern (*Gygis alba*), one of the most interesting and beautiful birds of Norfolk Island in the Western Pacific, about nine hundred and fifty miles north-east from Sydney. The bird breeds in densely wooded gullies, and it lays its single egg in a knot-hole or any slight depression on a more or less horizontal branch. It is difficult to think of any more hazardous situation. Mr. A. F. Basset Hull tells us that 'the sitting bird puffs out its breast-feathers so as to completely hide the egg, depressing its forked tail so as to obtain as secure a hold as possible, and sits with its beak pointing into the eye of the wind, so as to offer the least resistance'. Both parents share in the task of incubation, and we are not surprised to learn that they show great caution in rising and settling. It is the place chosen for the egg that chiefly concerns us, but we may finish Mr. Hull's interesting story.

'I saw the young bird, a ball of black down, squatting unconcernedly on the bare limb while its parents were away searching for food. A week later it was still there, and had then grown nearly as large as its mother, but it was still covered with the black down. Its mother flew up, and straddled over it, vainly endeavouring to cover it. There it sat blinking down at us, like a black piccaninny in the arms of a white nurse.'

Tadpoles of a Tree Frog.—To illustrate a cluster of adaptations, let us take Dr. W. E. Agar's account of the nest made by one of the tree-frogs, *Phyllomedusa sauvagii*. The adults are arboreal in their habits, and yet the tadpoles

develop in the water. This is, so to speak, arranged for by making a nest among the leaves of bushes overhanging the pools, and this nest breaks down at the appropriate time, allowing the newly hatched tadpoles to drop into the water. A number of leaves are held together by a deposit of empty gelatinous egg-capsules, such as we sometimes see in ordinary frog spawn—spheres of jelly without an egg inside. It appears that the gelatinous envelope characteristic of Amphibian eggs is adhesive when it is not in contact with water. Thus the leaves are more effectively held together. The cavity thus formed is filled up with a mixture of full and empty egg-capsules, and then there is a lid of empty ones on the top. It seems that the empty capsules not only keep the leaves together until the tadpoles are ready to drop out, but they form a protective shield lessening the risk of drying up. Dr. Agar observed that there was least mortality in the more perfect nests, so that the peculiarity of producing empty egg-capsules and the habit of using them is just such a peculiarity as would be fostered and fixed by Natural Selection.

Defiance of Handicaps.—There is in many creatures an extraordinary defiance of circumstances—a refusal to admit handicaps. There is an order of jellyfishes, well represented by the widely distributed green and blue *Rhizostoma pulmo*, in which the mouth is normally closed up by the lips so that only minute apertures are left along the lines of suture. This is intelligible, for the food is microscopic and the peculiarity is long established. But what are we to make of a case like the mouthless carp described by J. W. Fehlmann, which lived and throve, though its food-canal was mouthless and blind. That was severe handicapping, but the fish refused to die. It

lived for at least four years, feeding as well as breathing through its gill-clefts. It is possible that the carp was in part sustained by nutritive material in solution in the water, but there were numerous mayfly larvæ, crustaceans, pieces of plants and the like in the food-canal which must have passed in by the breathing apertures. It may be recalled that according to some speculative anatomists the present-day mouth of backboned animals arose from the fusion of two gill-clefts.

In any case, though the mouthless carp naturally enough showed no trace of fat, it lived for at least four years, and that is the sort of defiance of handicapping which we wish to illustrate.

Tenacity of Life

The toughness of some animals is extraordinary, and is often of considerable practical importance to man, for instance, when he is trying to rid his farm or garden of injurious insects. They are so difficult to kill. The explanation is in part no doubt that the chitinous cuticle is very impervious and resistant, and that larvæ in particular are able to close their mouth and breathing-pores. But there is a good deal left to explain. A very careful worker, L. Bordas, notes that he immersed potato caterpillars (*Phtorimœa operculella*) in 70 per cent. alcohol for six to eight hours, and found them still able to contract the body, and to move the head and limbs and jaws!

The larva of the cheese-fly, *Piophila*, can pass right through the alimentary canal of man and dog without being the worse for it, though the canal may be worse for them, as they scratch the delicate mucous membrane with their oval hooks. Alessandri put some for sixteen hours in

70 per cent. alcohol and others for thirty hours in petroleum, but they survived it all. Such is the toughness of some living creatures.

Some of the statements that have been made in regard to the survival of complex animals after prolonged and severe desiccation require to be revised. In some cases, at least, the creatures themselves die, but eggs with specially resistant envelopes ('winter-eggs') live on and rapidly develop when there is a restoration of favourable conditions. Thus D. D. Whitney (1908) found that out of forty-five different species of Rotifers, belonging to seventeen families, only two, *Philodina roseola* and *P. citrina*, could successfully withstand desiccation. It seems probable that the revival of adult Rotifers after desiccation is not so common as has sometimes been supposed.

An almost whimsical instance of vital resistance is vouched for by G. Tornier. He found two eggs of the common lizard, *Lacerta agilis*, through which the rhizome of a sedge had grown, dissolving away the shell at the entrance and exit. Each of the eggs contained a normal embryo! In the uppermost of the two eggs, which was perforated centrally by the rhizome, there were actually three rootlets penetrating the embryonic membranes and entering the yolk-sac. In one case a delicate rootlet had passed into the embryo's mouth. Yet the embryos were normal, illustrating quaintly but strikingly what we may call developmental resistance.

An eel about a foot long has been known to live for seventy-two hours without water, and a day's drought can be readily withstood. This tenacity of life makes it easier to admit the possibility of the overland journeys which eels are alleged to take when occasion requires.

Some interesting illustrations of tenacity of life have been afforded by recent experiments on the surviving-power of tissues cut off from the living body. In suitable culture-media they can be kept alive for many days and may even grow. At a variable point, differing for different tissues and media, growth becomes slow and stops and the living fragment dies. In this connexion Alexis Carrel has demonstrated a very instructive fact, showing that the death may be due to an accumulation of waste products and is not inevitable. If the dying fragment is lifted on a cataract-knife and bathed and fed, and bathed and fed again, it may get a new lease of life. It rejuvenesces. After nine washings a fragment of connective tissue grew with great activity on the thirty-fourth day after its excision from the organism. Thus, within limits, senescence and death are contingent, not necessary phenomena.

The automatism of part of a body is often gruesome. A turtle's heart will live for many days after its quondam possessor has been made into soup. A fractional part of a silk moth was observed by Professor V. L. Kellogg to 'live' for more than a day, responding to stimulus, and actually extruding the ovipositor and laying a few eggs. The separated anterior half of a wasp will go on sucking syrup, and the posterior half will sting. We are impressed on the one hand by the delicacy, on the other hand by the toughness of life.

The 'Big Trees'.—In the 'Big Tree' (Sequoia gigantea) of the western slopes of the Sierra Nevada range and in the 'Redwood' (Sequoia sempervirens) of the Coast Ranges, we have the impressive surviving representatives of an ancient genus (dating from the Cretaceous) that once spread over the Northern

Hemisphere, but was brought near to extinction by the severe conditions of the Great Ice Age. In size, majesty, vigour, recuperative power, age and antiquity these 'Big Trees' command our admiration. They have the distinction of having had a longer life than any other living creatures—they make centenarians and the like appear youngsters.

The late Prof. W. R. Dudley recorded some precise data on a subject which tempts to exaggeration. 'Of the various trunks of *Sequoia gigantea* examined ranging from 900 years upward, the oldest possessed 2,425 rings, or had begun its existence 525 years before the Christian era'. A tree near a perennial stream was over 80 feet in circumference, ten feet from the ground, but was only 1,510 years old; another growing on a hillside not near a stream, had suffered from fire and from privations (fifty rings of scarce years not covering an inch), and it was only 39 feet in circumference, ten feet from the ground, but it had attained the age of 2,171 years and a height approaching 300 feet.

Professor Dudley showed the extraordinary vitality of the Big Tree by tracing out the way in which many of them had been able to 'heal' or cover over great wounds made by fire. What a tree does is not to revitalize what has been killed—that is impossible—but to extend or fold its living tissue over the wound. 'There is no organic union between the new wood of the folds and the wood of the charred surface underneath them, no healing at this point of contact, in the ordinary sense of the word; but there is effectual *covering*, or healing in the rarer sense, according to the tree trunk's way.' The process may take scores of years.

The tree already referred to which began its existence in

271 B.C. was about twelve feet in circumference just above the base at the beginning of the Christian era. When it was 516 years old (A.D. 245) it suffered a burn three feet wide, and 105 years were occupied in healing this wound. When it was 1,712 years old (A.D. 1441) it suffered two bad burns. One hundred and thirty-nine years of growth followed, including the time occupied by the covering of the two wounds. When it was 1,851 years old (A.D. 1580) it suffered from a burn two feet wide which took 56 years to heal. When it was 2,068 years old (A.D. 1797) a tremendous fire burned a great scar 18 feet wide with a height estimated at 30 feet. In the 103 years that were vouchsafed to it before it was killed, the tree had reduced the wound to fourteen feet in width, and it might have finished it in A.D. 2250, or thereabouts. 'Sequoia gigantea stands practically alone, sublime among living objects in its ability to withstand an injury of this magnitude, and to endure a sufficient length of time for its complete recovery'. The resistance to insect, fungus, and microbe is hardly less remarkable. 'There is something in the sap of the Big Tree that is an elixir of life, something deposited in the lignified cells of the normally formed layers of wood that resists in an unexampled way the dreadful 'tooth of time'.

One does not envy the man who can look at even a section of great Sequoia without a thrill at the sight. 'We have, deep in their annual rings, records which extend far beyond the beginnings of Anglo-Saxon peoples, beyond even the earliest struggles for liberty and democracy among the Greeks', . . . 'records of forest conflagrations, of the vicissitudes of seasons, of periods of drought and periods of abundant and favouring rains'. It is to be hoped that everything feasible will be done to protect these triumphs

of life—these sublime instances of its power and endurance —which are certainly among the most remarkable products of the globe.

The recuperative power of races varies within wide limits, and it is often difficult to suggest why one type should have so little and another so much of it. The story of the tile-fish (*Lophobatilus chamæleonticeps*) is interesting in this connexion. It used to frequent the north-east coast of North America, in water about 50° Fahr., and was much fished between 1879 and 1882. In 1882, however, there was a very hard winter, culminating in a great storm which in one night almost put a full stop to the tile-fish. Over a sea-area of some 5,000 square miles the dead fishes were found on the surface in thousands—suddenly killed off by a fall of temperature below the limit of viability. No tile-fish was seen for ten years. But in 1902 the small remnant that must have escaped began to manifest itself, and the recuperation gradually set in.

Plasticity

Change of Habits.—The well-known robber-crab (*Birgus latro*) is a good instance of adaptability to a thoroughgoing change of habit. Birgus should be a seashore animal, and it has to return to the shore to spawn, illustrating the rule that the young have to be cradled in the ancestral headquarters, but it has become a terrestrial animal. It goes high up the mountains, and Dr. Andrews has photographed it climbing trees. It simply walks up, clinging by the sharp points of the walking-legs, hardly using the large claws at all. Of the robber-crabs at Christmas Island, Dr. Andrews writes that they are easily fright-

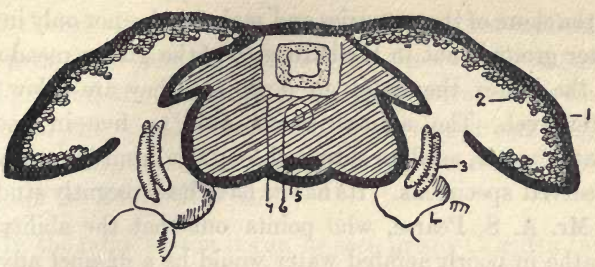


FIG. 37.—Cross section through a land-crab (*Birgus latro*). (*After* Semper.) 1. The over-lap of the cephalothorax shield. 2. The respiratory tufts. 3. Two small gills. 4. The base of a leg. 5. The ventral nerve-cord. 6. The food-canal. 7. The pericardium around the heart.

ened and scuttle off backwards, propelling themselves with their long anterior legs in a series of ungainly jerks. They seem quite conscious of the comparative defencelessness of the abdomen, which they endeavour to thrust under logs or into holes among the roots of trees. But they never carry any protective covering. Their dietary must also have changed greatly, for they eat fruits of various kinds (such as sago-palm and screw-pine) and carrion of all sorts. As their name suggests, they are incorrigible thieves, stealing from the camp not only what is or even looks edible, but apparently anything that has been handled, cooking utensils, bottles, and clothes. Dr. Andrews complains that he had a geological hammer practically ruined by having its handle splintered in the powerful claws of one of the robbers!

The case of the land-crab suggests another good instance of adaptation to change of habit. It is to be found in a Philippine crustacean, *Thalassina anomala*, which is in some respects like a link between the long-tailed prawn type and the hermit-crab type. It is a common burrower

by the shore of the estuaries and makes holes not only in the softer ground, but in the hard clay of the grassy meadows. In the latter the holes go down till they are below the water-level. The animal seems able to live in poorly aerated water, as Bate surmised long ago from his study of preserved specimens. Its habits have been recently studied by Mr. A. S. Pearse, who points out that the ability to breathe in poorly aerated water would be a distinct advantage, and seems to have been secured by a simple contrivance. The gill-covers or side-flaps of the shield that covers the front of the body are movable on the dorsal portion of the carapace by a sort of flexible hinge joint. 'An individual placed in a dish will often move the sides of the carapace in such a manner that it resembles a Vertebrate gasping for breath'. Such bellows-like movements must serve to hasten the current of water that is drawn in over the gills and thus facilitate respiration.

As a good instance of the possession of a new home we may refer to the freshwater sting-rays of the Ganges. No fishes are more characteristically marine than rays and skates, yet it is certain that there are several members of this (Batoid) family in the Ganges. Two species, *Trygon fluviatilis* and *Hypolothus sephen*, have established themselves far up the great river. Even one thousand miles above tidal influence, they thrive and breed freely.

While some creatures are sensitive specialists as regards environment, others are tough cosmopolitans. In illustration of the latter we may refer to Dr. Alcock's account of the freshwater crabs (Potamonidæ) of India. They are typically freshwater animals, but some can live both in brackish water and in damp jungle. 'They are found in ponds, lakes, streams, rivers, and marshes;

and though they flourish most at low or inconsiderable levels in the tropics they extend into the warmer temperate regions, and are also quite common at considerable elevations in the torrid zone.' As a particular example, he takes *Paratelphusa spinigera*, which is very common in the swamps of Lower Bengal.

'In the rainy season it can be seen in any Calcutta tank, often reposing on the bank, half immersed in the water: in the cold season it may be found in the jheels in swarms, half-buried in the mud: in the hot season, where the surface waters dry up, it digs deep burrows to get down to the ground water. The same species, *P. spinigera*, on the one hand, ascends the Ganges and Jumna as far as Hardwar and Saharanpur, and the Jhelum valley to an elevation of two thousand feet, and, on the other hand, does not object to the brackish water of the Gangetic delta.'

The Biology of the Seasons

We have given some examples of what might be called *the conquest of space*—the exploitation of the earth, the making the best of difficult conditions, the circumventing of obstacles; but there are other instances of the same quality of life which might be grouped under the title *the conquest of time*—the victory over temporal vicissitudes. This is in great part the theme of a previous study[1] and we shall confine ourselves here to a few illustrations.

The general problem is how living creatures suit themselves to the external periodicities of the seasons, or of day and night, or of oscillations of climate. In diverse ways the internal rhythms of life have come to be adjusted to the external periodicities. It is said that the tropical

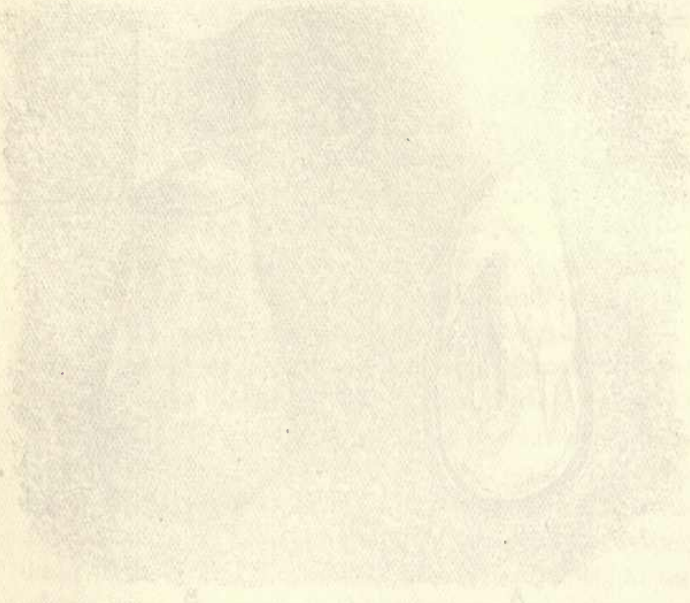
[1] *The Biology of the Seasons*, 1911.

African mudfish (Protopterus) taken to North Europe, and kept with abundant water, tends to become dormant at what corresponds to the African dry season, when it normally goes to sleep for half the year. It is said (precise facts would be very valuable) that migrant birds in cages become restless in autumn—at the proper time for southward flight—although they are living in conditions of apparent comfort. It is certain that many birds begin their autumnal migration with notable punctuality at a time when the external changes have not yet begun to be in any sense compelling.

The point may be further illustrated by reference to Professor Semon's suggestive experiments with young Acacias (*Albizzia lophantha*). They had never been exposed to the normal alternation of day and night, to which acacias are wont to respond by expanding or closing the leaves. Semon exposed them to artificial days and nights of six hours' or twenty-four hours' duration, but the young plants exhibited the twelve-hours' cycle quite unmistakably—though just a little altered. After this experiment, Semon exposed his plants to continuous darkness or to continuous illumination, and he had the satisfaction of seeing the twelve-hours' cycle still manifesting itself for a little. It gradually became indistinct, as the plants gave up asserting themselves against 'times out of joint'. At first, however, the experiments showed very beautifully how the ingrained hereditary periodicity may struggle against inappropriate external conditions.

It is interesting to consider the diversity of ways in which animals meet the difficulties involved in the winter-conditions in North Temperate countries. Many birds, 'intelligent of the seasons', as Milton has it, escape the

FIG. 38.—Protopterus. A. Capsule cut into, showing the coiled-up fish with its nostril at foot of the pipe (P). B. Capsule intact, showing lid (L). (*After* W. N. Parker.)



spell by flight,—a solution which we shall presently discuss in detail. Other creatures, unequal to the long and adventurous journeys of the birds, retire into winter-quarters, in which they lie low, awaiting happier days. Thus the earthworms burrow more deeply than ever below the reach of the frost; the lemmings tunnel their winding ways beneath the icy crust of the Tundra; all manner of insects in their pupa-stages lie inert within cocoons or other protective envelopes in sheltered corners; the frogs bury themselves deeply in the mud of the pond, and lie there mouth shut, nose shut, eyes shut, with the heart beating feebly, and breathing through their skin; and the slow-worms coil themselves up together in the penetralia of their retreats—all trying to get below the deadly grip of the frost's fingers, and usually succeeding. Let us take, as a diagrammatic detail, Professor Arnold Lang's observation, that the heart of the snail beats more and more slowly as the temperature falls and the animal sinks more deeply into hibernation. A heart that can beat fifty times a minute in summer may only beat 2·36 times a minute at a temperature of 2·65°C. in February.

Very effective, too, is the deep hibernation of such mammals as hedgehog, hamster, and marmot. The normal power of 'warmbloodedness', that is, of keeping an approximately constant body-temperature, is in abeyance for a time; the body cools to a degree which in ordinary life would be fatal; the fat accumulated in days of plenty is slowly burnt away; irritability wanes to a minimum and the ordinary reflexes are faint; the heart beats feebly; the breathing movements may be scarcely perceptible; the creature steadily loses weight. But it keeps alive!

Others, again, such as the Arctic fox, the mountain hare,

the ermine, the Hudson's Bay lemming, and the ptarmigan, face the dread enchantment of Winter, but turn paler and paler under the spell, until they are as white as the snow itself—a safety-giving pallor. They have a constitutional tendency to change their colour, and the external cold pulls the trigger that sets the process at work. The white suit is of service for concealment or in the chase, and it is also physiologically the most economical and comfortable dress for a warm-blooded animal when the external temperature is very low.

An interesting and unusual adaptation to the severity of winter is exhibited by the Canadian Ruffed Grouse (*Bonasa umbellatus*), which often takes refuge among the dry soft snow of drifts, having discovered its value as a non-conductor. It sometimes tunnels in, but it usually gets a start by diving from a branch or off the wing. It makes a passage about two feet long with an enlargement at the end, and may lie there for several days. Mr. Charles MacNamara observes that 'except for the one mark where the tunnel begins, the surface of the snow is quite undisturbed, and no one would ever suspect that a live warm bird was concealed in the drift'.

Migration as an Instance [1]

From ancient days the migration of birds has excited the wonder of all thoughtful observers. The author of the Book of Job took note of the hawk that stretcheth her wings towards the south; the Hebrew prophet in his message to Israel recalled the fact that 'the stork in the

[1] In taking this instance we have almost inevitably repeated part of the discussion of Migration to be found in several chapters of *The Biology of the Seasons*.

heavens knoweth her appointed time, and the turtle and the crane and the swallow observe the time of their coming'; and Homer made telling use of the familiar picture of the migrating cranes. We know much more about migration than did these early observers, but it can hardly be said that the wonder is less.

Sometimes the migratory movement is seen with almost startling vividness, so that even the careless are impressed; at other times the annual tide flows and ebbs without calling for much remark. On an island like Heligoland, which lies on a favourite migratory route and is without any resident birds of its own (save sparrows), it is very impressive to see wave after wave of migrants strike the rocky shore in the autumnal westward and south-westward movement. The birds used to light in thousands on the small fields now given over to batteries, and rest for a few hours before continuing their journey. Observers on the Isles of Scilly sometimes see hundreds of thousands of birds of the same kind flying from the English coast; and taking many hours to pass. And many who have travelled on a steam-ship up the West Coast of Africa in autumn have had the good fortune to see enormous numbers of birds making their way south, looking from a distance like dense clouds of smoke swirling rapidly close to the water. Some of the migrants often rest on the ship for a while, until they feel that they are being carried the wrong way. Then they rise into the air and make for the south again.

Not less interesting is it to watch the actual arrival of the summer visitors, especially when they come in after a long sea-voyage, and sink to the ground as if welcoming a rest. When one sees swallows and the like arriving on

the coast of Cornwall, for instance, one recalls Tennyson's picture—

> Faint as a climate-changing bird that flies
> All night across the darkness, and at dawn
> Falls on the threshold of her native land,
> And can no more.

But whether the migration be seen in a striking or in an inconspicuous form, it can never fail to produce the thrill of wonder in the reflective observer.

Lines of Inquiry.—It may be said broadly that there are three main lines of inquiry, each reasonable and promiseful. Each has indeed already led to important results. First, there is the method of registering the arrivals and departures, the changes and movements, in a small area like Heligoland or Fair Island, which can be thoroughly explored. We cannot mention these two islands without thinking at once of Gätke and Eagle Clarke. Second, there is the method of collecting data, year after year, from observers scattered over a wide area, both inland and on lighthouses and lightships, who record times of arrival and departure, great wave-like incursions, marked increase and decrease in numbers, and the like. This is the method, painstaking and laborious, and sure to yield generalizations in the long run, which has been followed for eight years now (1914) by the British Ornithologists' Club. Third, there is the method, which we may particularly associate with the name of Dr. Thienemann of Rossitten, of marking large numbers of migrants with indexed aluminium rings, in the hope of hearing again of the whereabouts of a small percentage in their winter-quarters or summer-quarters or en route between the two. This method has already led to the mapping out of a more than provisional migrational

route for the White Stork in its southward or south-eastward autumnal flight.

Some Fundamental Facts.—Migration is not to be confused with the invasion of a new territory in search of food and under pressure of increasing population—though it may have originated in some cases in this way. It is a regularly recurrent seasonal movement,—an oscillation between summer-quarters and winter-quarters, between a breeding and nesting place and a feeding and resting place. And one of the fundamental facts is that birds always nest in the colder area of their migratory range.

For the Northern Hemisphere it must be admitted that bird-migration is a general phenomenon, though it differs greatly in its range and conspicuousness. In many parts of Scotland the curlews pass at the beginning of winter from the exposed moorland to the neighbourhood of the sea-shore, where it is easier to procure food; and flocks of sixty or more of these shy birds are often seen at work among the jetsam. This is migration within a short radius. It may be contrasted with that of the Arctic tern which the *Scotia* explorers found 'wintering' in the Antarctic summer in 74° S. lat.—'the greatest latitudinal range of any vertebrate animal'.

It is said that many of the godwits which nest in eastern Siberia winter in New Zealand, but the 'ringing method' should be used to test these generalizations. It is certain, of course, that many godwits leave the north of New Zealand in spring, that many godwits nest in Eastern Siberia, and that many godwits return to New Zealand in October. It is necessary, however, to prove that the birds that spent some summer months in Siberia were the birds that enjoyed in the same year a second summer in New Zealand.

Referring to the general occurrence of migration, Professor Newton said—

'I cannot point out any species which I believe to be, as a species, entirely non-migratory. No doubt many persons would at first be inclined to name half a dozen or more which are unquestionably resident with us during the whole year, and even inhabit the same very limited spot. But I think that more careful observation of the birds which are about us, to say nothing of an examination of the writings of foreign observers, will show that none of them are entirely free from the migratory impulse.'

He instanced the Hedge Sparrow which seems so stationary on Britain, and yet is well known as a migrant on the Continent.

Our knowledge of bird-movements in the Southern Hemisphere is very scanty, and must be left out of account at present; but for the Northern Hemisphere it is a very familiar fact that the birds of any country can be classified, from the migration point of view, into five sets :—

(1) There are the summer-visitors, such as swallow, swift, cuckoo, nightingale, and so on through the long list (mostly insectivorous, one should note), who arrive from the South in Spring, nest and breed within our bounds, and return in late summer or autumn 'to warmer lands and coasts that keep the sun'.

(2) Against these we have to place the winter-visitors, such as fieldfare and redwing, both first cousins of the thrush, the snow bunting, and many of the northern ducks and divers, who nest in the far North, but come South in winter.

(3) In a set by themselves we may rank the birds-of-passage in the stricter sense, like some of the sand-

pipers, the great snipe, and the little stint. They rest for a short time only in a country like Britain, on their way further south or further north.

(4) Then there are the 'partial migrants', who are always represented in the country or area in question, but not always by the same individuals. That is to say, some individuals leave the country and others do not; and the place of those who go is often taken by other individuals from elsewhere. Thus in many parts of Scotland one may see lapwings every month of the year, and yet there is a regular autumnal migration of lapwings from Scotland to Ireland. There are always goldfinches to be found in the South of England, but there is a regular migration southwards in October and a corresponding return in April. Recent research has shown that the list of 'partial migrants' is a long one,—longer than used to be thought.

(5) There remain the strictly resident birds—such as, in Britain, the red grouse and the house sparrow (to take a sacred and a profane example). The rook and the robin may serve as two other instances. But the list has been greatly reduced by the discovery that many of the reputed residents are really partial migrants. It is obvious that no hard and fast line can be drawn; and it goes without saying that species which are resident in one country may be migratory in another, just as the summer-visitors of one country are of course the winter-visitors of another.

Perhaps another division should be made for the interesting 'casual vagrants' who occasionally turn up in a country, far off their normal line of movement. The American Kildeer Plover shot in Aberdeenshire in 1867 is a good instance.

The migration of birds is a seasonal phenomenon, and it seems legitimate to rank among the fundamental facts the contrast that obtains between the autumnal and the vernal movements. There is some uncertainty in regard to various features of the contrast, but that it is marked must be admitted. The autumnal migration, on the whole southwards, is less intense than the return migration in spring. One often observes a good deal of preliminary fuss and not a little dallying before the autumnal migrants get fairly under way. They make trial journeys and may begin their pilgrimage with short stages. The young birds are said to get restless first; the old males are said to linger longest. It may be that the adults are kept back by the need of recuperation after their family cares, and also by a moult after which the feathers damaged by the summer's wear and tear are replaced. Every one knows the exceptional case of the cuckoo, whose offspring, carefully fostered by other birds, do not leave Britain for six weeks or so after all their real parents have gone.

In spring, on the other hand, the movement is much more intense, impetuous, and urgent. The adult males seem usually to take the lead, 'love-prompted'; then follow the adult females; the immature birds, who will not breed for a season or two, bring up the rear. Thus the vernal order is the reverse of the autumnal order. There is some evidence, also, that the spring journey is more direct than the autumn journey. Shortcuts are found and impelling haste is the characteristic feature. Where the sexes fly separately, it may be that this is because they naturally fly at different rates.

As a striking illustration of the contrast between the vernal and the autumnal migration movement, we may

recall Audubon's observation in reference to the Rice Bird, Dolichonyx oryzivora, that it flies in Spring by night, and in Autumn by day.

Another general fact that impresses us in regard to migration is its regularity and success. When weather conditions are very unpropitious, there is often great mortality. The streets of towns are sometimes strewn with the corpses of thousands of birds that have gone astray and succumbed to the cold. As many as five hundred nightingales have been gathered in a single day from one small town. Large numbers of migrants perish every year by dashing themselves against the windows of lighthouses. But, on the whole, the striking fact is not the number of failures but the large proportion of successes. This is the more striking when the difficulties of a long migration-journey are borne in mind. What we are made to feel is that migrating is an old-established business; it has been going for so many hundreds of thousands of years that it has acquired a certain smoothness. A thrush born in the North of Scotland was found at the end of its first summer near Lisbon—a long journey for an inexperienced traveller who is hardly counted as a migrant at all. And there are many similar instances.

The feature of regularity is also illustrated by the remarkable punctuality of arrival and departure which is usually exhibited, except, indeed, when the meteorological conditions are unusual. Fog and head-winds may delay arrival; a summer that has favoured the increase of insect life may induce birds to postpone their departure; but, on the whole, there is a remarkable temporal regularity in the comings and goings.

While there is great regularity in many cases, it must

also be borne in mind that certain of our summer visitors in Britain keep on arriving for a long time—different contingents probably coming from different winter-quarters. Thus in the sixth Report of the Migration Committee of the British Ornithological Club it is recorded that 'the immigration of the wheatear (including both races) extended over a longer period than that taken by any other species, the first arrivals (in 1910) being observed on March 6, the last on May 19. Other species occupying a prolonged period were the willow-warbler (March 19 to May 19) and the whin-chat (March 26 to May 23), while the shortest time seems to have been taken by the wood-warbler (April 11 to May 6). The average length of the arrival period for 1910 was about five or six weeks'. For the same year the first bird to return was the chiff-chaff on March 5, but except for a few species the immigration did not really set in till April 2. Most of it was over by the end of the third week in May. The largest movement occurred on May 2, when no fewer than twenty-five different species arrived simultaneously on the British coasts.

On the whole, however, the regularity of the migratory movement is impressive, and Professor Alfred Newton wrote thus about it long ago—

'Foul weather or fair, heat or cold, the puffins repair to some of their stations as regularly on a given day as if their movements were timed by clock-work. Whether they have come from far or from near we know not, but other birds certainly come from a great distance, and yet they make their appearance with scarcely less exactness. Nor is the regularity with which certain species disappear much inferior; every observer knows how abundant the swift

is up to the time of its leaving its summer home, and how rarely it is seen after that time is past.'

Still more remarkable is the fact of spatial regularity. For in a few cases (doubtless to be increased) we have conclusive proof of a bird's return to its birthplace. A swallow marked as a youngster with an aluminium ring has been known to return the following year, not merely to the same county or parish, but to the same farmyard—a striking instance of precision in the sense of locality, and of a constitutional home-sickness bringing the bird back from its winter-quarters (probably in Africa) to its birthplace in England. The same return to the original homestead has been proved in the case of the house-martin and the stork, and is certainly one of the most wonderful facts about migration.

Concrete Problems of Migration.—One of the important questions which patient investigations, like those of Mr. Eagle Clarke, are in process of answering, concerns the routes which birds follow in their migratory flight. On the basis of observations made at lighthouses and lightships and at strategic inland stations, it has been possible to map out certain favourite routes. Equally useful results have rewarded ' the ringing method ' pursued by Dr. Thienemann at Rossitten, Dr. Mortensen in Holland, Aberdeen University and the editor of *British Birds* in Britain, and by others on the Continent and in the United States.

The localities where any particular kind of bird was originally ringed and was subsequently captured, are registered on a map (a different one for each kind of bird), and as the records of rings accumulate in the course of years the distribution of dots or crosses on the map begins to

show the nature of the migratory movement with an accuracy proportionate to the number of data. The marks may show an irregular diffusion over a wide area, which would indicate the absence of well-defined paths; or they may show a definite strand or curve, which would indicate one of the favourite paths. Thus Dr. Thienemann has been able to trace the migration of the stork with considerable precision. There is an autumnal movement from the north to the south-east as far as South Africa; and a vernal return to the natal district, sometimes within a few miles of the birthplace, was proved in some cases. The rings were returned from Damascus, Alexandria, the Blue Nile, Rhodesia, and further south. One of the birds recorded from the Kalahari desert, 8,600 kilometres from its northern home, had been killed for food by a native, who threw it away, as uncanny, when he caught sight of the ring. Two young storks, nine months old, were found in Basutoland, 9,600 kilometres from home.

In the same way it has been made clear that there is among hooded crows, for instance, a great westward movement in autumn, e.g. from Finland along the shores of the Baltic, and that there is a subsequent curve towards the South. This westward and then southward curve seems to be true of many birds in North Europe. Certain contingents seem to swerve southwards by the valleys of the Rhine and the Rhone, and then across the Mediterranean to North Africa. Other contingents seem to go further westwards, crossing, it may be, by way of Heligoland to the South of England, and thence across to France, Spain, and Portugal, finally landing like the others in North Africa. For some other birds, like the swallow and the Red-Spotted Bluethroat, there is considerable

evidence of a more direct north to south movement in autumn. Large numbers of swallows are seen in autumn making their way down the west coast of Africa, perhaps reaching the Cape; those from Eastern Europe are said to work their way southwards by the Nile Valley. Corresponding species or varieties in North America seem to fly to Brazil, and in North Asia to Burmah.

It is not merely in regard to the routes followed by migratory birds that we are in ignorance; we are in most cases quite unable to say where our summer visitors pass the winter. We know that they leave us for the south, and we know that birds of that kind become numerous in the late autumn in some other area—the shores of the Mediterranean, Arabia, West Africa, South Africa and so on, but what we wish to be able to do is to make a precise statement to the effect that certain summer visitors of the Midlands of England spend their winter on the Gold Coast or elsewhere. Perhaps this will eventually become possible if the bird-marking method is prosecuted for a long stretch of years. Another question of great interest, which must wait for its answer until many more data accumulate, is whether the return-journey in spring is by a route different from that of the autumnal journey.

Other matters for investigation, which must be patiently continued without hurrying towards an answer, are the altitude and the velocity of the migratory flight, and its relation to weather-conditions. While enormous armies of larks, starlings, thrushes, and some other birds have been seen flying very low across the sea, it is probable that most migrants fly at a considerable height. Careful observations made by von Lucanus lead to the conclusion that it is very unusual for birds to migrate at altitudes above

3,000 feet. Some astronomers, however, report seeing birds at elevations of 10,000 feet.

Gätke estimated the speed of migrating plovers, curlews, and godwits, crossing Heligoland, at nearly four miles a minute, and he calculated the speed of Hooded Crows, crossing the North Sea, at 108 geographical miles per hour. He credited the little Northern Bluethroat with a velocity of 180 geographical miles per hour. It seems to be the general opinion of experts that these figures are far too high. Dr. J. Thienemann's observations at Rossitten in 1909 led to such averages as the following: Sparrow-Hawk, 25⅞ miles per hour; Hooded Crow, 31¼; Rook, 32½; Chaffinch, 32¾; Linnet, 34¾; Peregrine Falcon, 37; Jackdaw, 38½; Starling, 46⅓. Some other careful observers have estimated the migratory rate of many birds at about a hundred miles an hour. It is reported that a marked swallow flew from Compiègne to Antwerp, about 145 miles, in 1 hour 8 minutes!

It is certain that many a bird may attain in its everyday life to a velocity of fifty miles an hour, and it is probable that twice as fast is a safe estimate for the rate of many a migratory flight, when the whole life is raised to a higher pitch.

And as to meteorological conditions it becomes increasingly clear that birds in their migrations are somewhat strikingly indifferent to the weather, unless, indeed, it reaches a high degree of storminess or fogginess or unpropitiousness generally. It seems that the weather-conditions which obtain when and where a mass-movement begins are of much more moment than those into which the birds pass in the course of their flight.

Deeper Problems of Migration.—It is interesting to

inquire where we should rank migration on the inclined plane of animal activities, but no secure answer can be given in the present state of science. It seems to partake very largely of the nature of instinct, that is to say, birds have a specific hereditary preparedness or disposition for their migratory movements, which enables them to go through with them without education or experience. But this does not exclude the view that birds have their wits about them as they fly, for many instinctive activities show a spice of intelligence. Nor does it exclude the view that birds migrate more successfully as they grow older, for instinctive routine may be intelligently perfected by practice. That the migratory activity has an instinctive basis is suggested by its regularity and orderliness, without much individuality and with little hint of caprice; by the preparations made before there is any real need; moreover it must be remembered that none of our summer visitors have any personal experience of wintry conditions, literally knowing no winter in their year; by the success with which many young birds carry it through, apparently unguided and untutored; by a few observations of the restlessness shown at the proper time by comfortably caged migrants; and by the sporadic occurrence of other true migrations in widely separated divisions of the animal kingdom.

Periodic movements occur in many other creatures besides birds—in landcrabs, in fishes like salmon and eel, herring and mackerel, in turtles, in lemmings and field mice, in some deer, in eared seals and in most cetaceans, such as the bottle-nose whale, the right whale, and the white-beaked dolphin. The term migration should not be used, however, without qualification, unless the movement is really

periodic—a recurrent seasonal movement. Thus we regard the turtles' voyage to the egg-laying beach as migratory, while the lemmings' march is not. Similarly the movements of the salmon and the eel are much more worthy of being ranked as migratory than are those of the mackerel and herring.

The movements of whales are believed to depend in great part on the distribution of the organisms on which they feed, and perhaps in part on ocean currents. But according to Guldberg, there is also a reproductive factor. Gravid females seek calm and shallow waters. It must be remembered, however, that distance does not count much with these powerful swimmers, and just as a gull may cross the Atlantic (Germany to Barbadoes) without the fact meaning very much, so a whale's movements may be much less significant than those of a salmon.

If it be granted that the migratory activity has an inborn instinctive basis, we look none the less for the immediate causes or stimuli which pull the trigger twice a year at the proper time. In the case of the autumnal movement, we think of the increasing cold and the decreasing shelter, of stormy weather and the shortening of the daylight hours available for food-collecting, and of the dwindling supply of insects and slugs, fruits and seeds, and so on. But we shall probably go wrong if we regard these unpropitious conditions as more than liberating stimuli, which act on a prepared state of mind.

The stimuli that prompt the northward journey in spring are more difficult to state, especially when we take into account the great diversity of the winter-quarters and the fact that a large proportion of the returning migrants are immature. Probably the conditions of temperature,

humidity, and food supply are such as to exclude, for many kinds of birds, the possibility of nesting in the south. Perhaps in some cases the bird's constitution is such that it cannot become reproductive without the subtle stimulus implied in a return to the conditions of the original birth-place. Perhaps too there are lingering memories of the abundant and pleasant food—whether berries or mosquitoes—to be had in the North. Both on the reproductive and on the nutritive side there may be a sort of constitutional home-sickness.

It is difficult to get beyond mere speculation in regard to the origin of the migratory activity. The living organism is not merely a responsive plastic system which the environment subjects to various experiences; it is a creature that experiments. Migration was an experiment, an 'inborn inspiration',—probably to begin with of germinal origin—in the face of untoward conditions. The new line of solution, peculiarly natural to a flying creature, was to evade the difficulties, instead of facing them. Thus, instead of hibernating or laying on fat or making a great store of food, birds migrated before the approach of winter. It was a stroke of genius to discover that the prison doors were open.

Our view, then, is this, that an original instinctive mutation must be postulated, which amounted to 'a new idea', but was not an idea, which found expression in a timeous restlessness, in sensory alertness, in adventurous experiment, and in a power of flying more or less in one direction. Perhaps we see something like the beginning of it to-day in animals which seem to be sensitive to remote warnings of an impending storm, and take refuge accordingly. Given a beginning, we can understand the diffusion,

augmentation and specialization of the migratory instinct on ordinary Darwinian lines. Discriminate elimination of the dull, the sluggish, the wilful, the inexpert would gradually raise the standard of migratory capacity millennium after millennium.

As to the actual historical conditions that justified the migration experiment and sustained the discriminate elimination of the inexpert, there are two theories, both of which may be true. On one theory, our present-day summer visitors were once at home over a great part of the Northern Hemisphere which once had a much warmer and more equable climate than it now enjoys. Then there was no need for much migration, though most of the birds would probably seek to get away from the warmer areas at the breeding and brooding time, and away from the more exposed northern outposts when winter came. But if the climate changed and became steadily more severe, if the winters lengthened and the snowline crept lower and lower down on the mountains, if great glaciers spread southwards, and so on, then very gradually birds had to migrate further and further south in winter and were able to penetrate less and less far into the north in spring. When the climate changed again for the better, and the ice retreated pole-wards, there came about a re-colonization of the North Temperate zone as a breeding area. There was a return to the old racial haunts which the Ice Ages had rendered temporarily uninhabitable.

In general terms, then, the present-day spring migration northwards implies an organic reminiscence of the original headquarters before the Ice Ages; and the present-day autumn migration southwards implies an organic reminiscence of the second home which was discovered under the

stress of the glacial intrusion. But too much must not be made of the Ice Age, since we know that there is migration in the Southern Hemisphere as well as in the Northern.

The other theory, for which there is perhaps most to be said, lays the emphasis on the food-supply. Many birds are prolific, and overcrowding is apt to occur. Instead of crowding in one area all the year round, and involving themselves in want, birds learned, like the Swiss peasants, to exploit two areas, each for about half of the year. They tended to push further and further northward in spring, exploring and exploiting new grounds, staying as long as they could, and retreating before the breath of winter to their old home in the south, or, in many cases, far beyond that. It was probably most effective to go as far north as possible before settling down to family life. A noteworthy fact is that the more prolific birds tend to have the wider migratory range.

The importance of natural selection in connexion with migration was clearly pointed out by Alfred Russel Wallace in 1874 :—

'It appears to me probable that here, as in so many other cases, "survival of the fittest" will be found to have had a powerful influence. Let us suppose that in any species of migratory bird, breeding can as a rule be only safely accomplished in a given area ; and further, that during a great part of the rest of the year sufficient food cannot be obtained in that area. It will follow that those birds which do not leave the breeding area at the proper season will suffer, and ultimately become extinct ; which will also be the fate of those which do not leave the feeding area at the proper time. Now, if we suppose that the two areas were (for some remote ancestor of the existing species) coincident, but

by geological and climatic changes gradually diverged from each other, we can easily understand how the habit of incipient and partial migration at the proper seasons would at last become hereditary, and so fixed as to be what we term an instinct. It will probably be found that every gradation still exists in various parts of the world, from a complete coincidence to a complete separation of the breeding and subsistence areas ; and when the natural history of a sufficient number of species in all parts of the world is thoroughly worked out, we may find every link between species which never leave a restricted area in which they breed and live the whole year round, and those other cases in which the two areas are absolutely separated' (*Nature*, October 8, 1874, p. 459).

Way-Finding.—The most fascinating question in regard to migration is the one whose solution is probably most remote, *How do the birds find their way?* It is in agreement with scientific method that instead of giving too much time to speculation on this theme, we should devote years of patient investigation to the much humbler question, *What way do they find?* After years of devotion to the less ambitious question, we shall probably be able to ask the more fascinating question in some more hopeful form.

No doubt the wonder is great that birds return from the south to their birthplace in the north ; that inexperienced young birds make a long journey, often over-sea, to suitable winter-quarters, with success in a large proportion of cases ; that they keep their direction in the dark and at great heights, and while flying over the pathless sea. It is true that there are many failures, a crop of tragedies every year, a never-ceasing process of discriminate and indiscriminate elimination, but the marvel is the relative

success of one of the most daring of life's experiments. Let us glance very briefly at the various suggestions that have been made in regard to the way-finding. (1) It has been suggested that success in way-finding may be due to inherited experience, slowly cumulative from generation to generation, enriched and specialized by individually minute contributions. There is probably very little soundness in this suggestion, for we have no secure evidence of the direct entailment of the results of experience, and we find it difficult to state what *content* the experience could have in the case of birds flying by night, and often at great heights, and across the sea, as so many do.

(2) An attractive theory is that of social tradition, and in this there may be some truth. The idea is that those lead well one year who followed well for several years before. Ornithologists are not quite omniscient; there may be some old experienced hands amongst that rushing troup of youngsters. But the difficulties are great. How could the old hand become *experienced* in the matter of a night journey across the Mediterranean? In the case of the cuckoo there does not seem to be a single adult left in Britain when the youngsters begin to migrate. But there is no evidence that cuckoos are less successful migrants than other birds. It has been said that they may migrate with their foster-parents, but this, if true, cannot be the whole truth, since a number of the species who act as foster-parents are non-migratory birds.

(3) A third theory, that has a great deal to be said for it, lays all the emphasis on sensory acuteness. Birds have very keen senses of sight and hearing; the migrants *sometimes* follow coast-lines, river-valleys, lines of islands, and so on. But it is quite plain that this cannot be the

whole answer, since many birds migrate by night and at considerable altitudes. Nor are there any landmarks in the open sea.

(4) The fourth suggestion has almost certainly a high degree of soundness, that birds have in a sublime degree 'a sense of direction', which is expressed in two forms—as a capacity for flying continuously in a definite direction, and as a capacity for 'homing'. In regard to the second form we have some data, for the 'homing' powers of cats and dogs, cattle and horses, are well known. Even when the cat is put in a basket, and taken in a cab, and then in a train, it may find its way back. It is true that we do not hear very much of the cats who left their second home and did *not* return to their first home, but the positive cases are very interesting. There are some striking facts to which we shall refer in the chapter on Animal Behaviour, which go to show that if a hive-bee, issuing from the hive, be caught and imprisoned in a box and put into a pocket, and be thus transported for an intricate half-mile, and then released, it ascends into the air, and makes a 'bee-line' for home. The 'homing' of pigeons is also a familiarly established fact, and the value of it is not lessened by knowing that the power can be greatly increased by training. In fact, it seems legitimate to suppose that birds have in a sublime degree the sense of direction and the homing faculty. But all that we can say is, that this not unwarranted assumption makes the problem of way-finding less of an isolated riddle.

A Particular Case.—A story that may well excite admiration is that of the Pacific Golden Plover (*Charadrius dominicus fulvus*), large numbers of which winter in the

Hawaiian Islands, which are about 2,000 miles away from any continental area. Mr. H. W. Henshaw suggests that the islands were accidentally discovered by storm-driven waifs who were blown out to sea when following their usual southward migration route along the Asiatic coast in autumn. In any case the islands have become favourite wintering grounds, and the migration to and fro has come to be a regular recurrence. The birds leave the islands in spring in very good condition and probably fly straight on across the ocean, without feeding or resting, till they reach, it may be, the Aleutians. There is good reason to believe that many of the Golden Plover breeding in Alaska are from Hawaii, and that many of those that arrive in Hawaii in autumn have been in Alaska. 'It thus appears', Mr. Henshaw says, 'that thousands of birds, large and small, make a 2,000-mile flight from Alaska to Hawaii in fall and return in spring'. The flights are hazardous and many are lost, but the marvel is that so many are successful.

'What at first might appear a physical impossibility—the 2,000-mile flight of small birds across an ocean highway without a single landmark and with only the friendly winds to guide them, if indeed they utilize these as guides—is not only possible, but the feat is accomplished annually by many thousands of individuals, and apparently with no stops for rest or food. The wonder of it is increased when we realize that these annual flights are undertaken solely for the purpose of making a sojourn of a few brief weeks in Alaska to nest and rear their young.'

Mr. Henshaw falls back on the hypothesis of 'a sense of direction tantamount to a sixth sense'. The confidence with which the migrants launch out from Hawaii into the trackless waste certainly gives us pause.

Even if we postulate that they know how to make a journey that they have made before, and that young birds serve some apprenticeship, there rises the further question, Why do they launch forth at all? The departure from Alaska in autumn is obviously intelligible, they must flit or starve; but why do they leave Hawaii? There is plenty of room and plenty of food, and some American birds—a stilt, a night heron, a gallinule, a goose, a short-eared owl, and a buzzard—which probably came as waifs, like the Golden Plover, have become resident Hawaiian birds. Why does not the Golden Plover become a resident? The probable answer is a purely biological one, that, as Mr. Henshaw suggests, the Golden Plovers were originally Arctic birds, and that they have a homing impulse, a constitutional desire to return to their cradle-country, the Northern paradise from which the ice once expelled them. We agree with this observer in adopting the hypothesis of an organic home-sickness which prompts a return at the breeding season to the original headquarters or somewhere in that direction.

Retrospect.—A few examples may be as effective as many thousands to illustrate that quality of living creatures which every one in some instance or other has had occasion to admire. When we watch the literal legions of starlings circling over their resting-place on Cramond Island in the Firth of Forth, or the living cataract of guillemots, razor-bills, and puffins that descends from one of the great bird-bergs of the North when we rattle the oars in the boat, or a swarm of locusts in South Africa darkening the sky with a thick curtain of wings, we feel the insurgence of life. When we watch the flying-fishes rise in hundreds before the prow of the steamer, like grasshoppers in a meadow; or

the storm-petrels flying over the waves with dangling feet, never touching land except to nest; or the salmon leaping the falls; or the elvers on their journey up-stream, we feel again the insurgence of life. When we gaze at the cut stem of the Sequoia, which was a sapling a few years after the Fall of Rome, we are in presence of another form of the Will to Live. When we consider, as we have been doing, the fascinating wonder of bird-migration—one of the great adventures of life—we have a fine expression of the same quality. But, most of all, when we come to reckon with the history of organisms, when we see life slowly creeping upwards through the ages, adapting itself to every niche of opportunity, expressing itself progressively with increasing freedom and fullness, do we realize what is meant by insurgence.

CHAPTER IV

THE WAYS OF LIFE

(Modes of Animal Behaviour)

'Each of her works has an essence of its own; each of her phenomena a special characterization; and yet their diversity is in unity. . . .'

'She has always thought and always thinks; though not as a man, but as Nature. She broods over an all-comprehending idea, which no searching can find out. . . .'

'She creates needs because she loves action. Wondrous! that she produces all this action so easily. Every need is a benefit, swiftly satisfied, swiftly renewed. Every fresh want is a new source of pleasure, but she soon reaches an equilibrium.'

'She has neither language nor discourse; but she creates tongues and hearts, by which she feels and speaks.'

—*Goethe's Aphorisms*, translated by Huxley.

What is Animal Behaviour?—Behaviour of the Lower Animals:—Tropisms and more than Tropisms—The Study of Animal Instinct—Instances of Instinctive Behaviour—The Tale of the Black White Ant—Specialized Character of Many Instincts—Limitations of Instinct—Some Difficult Phenomena: 'Feigning Death', 'Bluffing', 'Homing', 'Masking'—Intelligent Behaviour—Instinct and Intelligence—Educated Animals.

THERE can be no doubt that investigators of animal behaviour during the last quarter of a century have been much less generous than their predecessors, and that they have in their parsimony greatly advanced our understanding. For it is an important rule in science to make the

most of the simpler factors before calling in the aid of the more recondite. The danger lies in going too far in this direction, trying to force upon facts a simplicity which does not fit them.

The older naturalists were inclined to be too anthropomorphic in their view of the lower animals, reading the man into the beast without scruple, and accepting anecdotes of animal intelligence on their face value without criticism. It was often very pleasing, this interpretation of animals as homunculi of the 'Brer Rabbit' type, with all the human faculties in miniature, except perhaps reason; but it was not good science. The reaction came inevitably, and about 1900 we find investigators like Bethe, Beer, and Uexküll declaring that it was time for biologists to give psychology a rest and to tackle the problems of animal behaviour biologically. And some have been so satisfied with their biological interpretations—in terms of nerve and muscle, protoplasm and its metabolism—that they have put 'the animal mind' entirely on the shelf, for certain sections of the animal kingdom at least.

What is Animal Behaviour?

Metabolism.—The living creature is always undergoing change, even when it rests; for life is essentially activity. Only in states of 'latent life' and the like does the ceaseless combustion and stoking, waste and repair, running-down and winding-up, come to an approximate standstill—from which it is easy to pass into death. But the ceaseless metabolism is not what is meant by *behaviour*.

Everyday Functions.—In every animal there are five everyday functions or activities. There are what Sir Michael Foster called the two 'master-activities' of

movement and feeling, or *contractility* and *irritability*, connected with the muscular and nervous systems respectively, if these are differentiated. These two master-activities make life worth living. To keep them a-going there are the auxiliary functions of (*a*) *nutrition* including the ingestion, digestion, and absorption or final incorporation of nutritive material; (*b*) *respiration*, including the absorption of oxygen, which may almost be called a gaseous food, to keep the vital combustion a-going, and the elimination of carbon dioxide, which is a gaseous waste; and (*c*) *excretion*, or the filtering out of the nitrogenous waste. Now these five everyday functions are the conditions of behaviour; yet behaviour means something more. In the same way, the periodic functions of *growth* and *reproduction* may be said to condition behaviour, but they do not necessarily involve it.

The beating of the heart is a very vigorous activity, going on, as we say, 'automatically'. It is in reality, of course, very subtly controlled by the nervous system, and can adjust itself to varying conditions within the body. We may take it, however, as a good type of *automatic internal activities*, such as the respiratory movements and the quiet work of liver and kidneys also illustrate.

Reflex Actions of Parts of the Body.—When we quickly draw away our finger from a hot surface, or close our eye against an approaching ball, or cough when a crumb of bread threatens to go the wrong way, we are illustrating relatively simple reflex actions of parts of the body. A stimulus from the outer world affects a sensory nerve, a message passes to the central nervous system, and a response quickly passes down a motor nerve, commanding a muscle or several muscles to move. In essence, reflex

actions involve (1) a receptor of a stimulus—a sensory or perceptory nerve-cell—from which impulses pass in to the central nervous system, (2) a 'motor' nerve-cell which connects the central nervous system with a muscle or a gland, and (3) between these two a 'communicating' nerve-cell connecting them within the nervous system. The three structural units taken together constitute a reflex arc, but in actual fact reflex actions are always more complex than this diagrammatic analysis suggests and cannot be isolated, except in theory, from other reflexes to which they are linked.

When a single-celled organism contracts itself or draws away from a stimulus—the simplest sort of response that a living creature can make—it seems most convenient to use the term *reaction*, keeping the term *reflex action* for multicellular animals in which there are differentiated elements forming a reflex arc. From simple reflex actions, such as drawing the finger away from a hot object, there is a graduated series leading on to such complicated reflex actions as coughing and sneezing and sucking.

Reflex actions require no attention, no will, no consciousness, no brain; they are invariable reactions of parts of the body to a particular stimulus, and depend upon preestablished structural arrangements and functional sensibilities. It seems convenient to admit that they hardly rise to the level of behaviour, for that term implies that the organism as a whole is an agent and that it exhibits a concatenated series of actions. In behaviour there is a more or less effective succession of adjustments of the whole creature. That the links of the chain may be reflexes, is a view held by many investigators.

Above reflex actions of parts of the body may be ranked a series of movements—often called tropisms—such as movements towards the light or away from it, towards warmth or away from it, towards one chemical substance and away from another.

Then comes the great range of instinctive behaviour, differing in a broad way from reflexes and tropisms in its greater complexity of concatenation, differing in a broad way from intelligence in its fixedness and in its independence of experience. That it is very frequently influenced by intelligence is generally admitted.

The higher grade of behaviour which we call *intelligent* is marked by conscious control, by learning, by profiting from experience, by 'perceptual inference', and often by experimenting. In the individual life-time a piece of behaviour which required intelligent control to start with may by dint of repetition cease to require this and become *habitual.*

In some human actions there is a control of behaviour in reference to general ideas, there is 'conceptual' instead of 'perceptual' inference, and to this the term *rational conduct* should be restricted.

Behaviour looked at without Analysis.—Before going further, it may be useful to look at the general business of animals, without raising any of the very difficult problems regarding the relative status or significance of different kinds of behaviour. What is it, on the whole, that animals busy themselves with? We must answer, with Prof. M. F. Guyer, that 'Animals, from their own point of view, have two, and only two, occupations in the world. These are (1) to care for themselves, and (2) to care for their offspring. Consequently, every important thing to be

seen about an animal has to do with one or the other of these pursuits'.

Thus we see animals seeking for food, storing it, making shelters and homes, adjusting themselves to the inanimate world, e.g. in migration and concealment; adjusting themselves to other creatures, e.g. in combat and flight; seeking and finding mates, preparing for the young, feeding and otherwise caring for the young, and so on. There may also be play during the early part of life, courtship at adolescence, division of labour within a community, and co-operation in societary enterprises, such as building a dam or going on a slave-making raid.

Behaviour of the Lower Animals:—Tropisms and more than Tropisms

Tropisms.—In the lower animals, according to Loeb, Bohn, and others, we must recognize the general occurrence of 'tropisms' and allied reactions. Every one knows that plants growing in a window bend towards the light, and this is said to come about automatically, simply because the side away from the light grows more quickly. We do not need to suppose that the plant longs for the light. In the same way animals may move towards the light without 'willing' to do so. Prof. Jacques Loeb has explained what happens. When the light comes from one direction and strikes one eye, it sets up chemical processes in one eye which are different (e.g. quicker) than those in the other. But this affects the nerves and muscles of the illumined side and the creature moves towards the light. For it is usually a bilaterally symmetrical animal, and

it is more comfortable for it to have its chemical processes in equilibrium, and its two eyes equally illumined.

Tropisms, then, are obligatory movements which result from a difference in the rôle of chemical processes on the two sides of the plane of symmetry. Thus we have phototropisms, or obligatory reactions in relation to a light stimulus, the creatures sometimes moving towards it, like some moths, caterpillars, and fishes, which are said to be positively heliotropic; and sometimes away from it, like earthworms, maggots, and freshwater Planarians, which are said to be negatively heliotropic. In the case of fixed animals, like sedentary worms, the reaction may be simply a bending towards or away from the light.

Similarly, there are tropisms in relation to gravity (geotropism), in relation to currents or pressures (rheotropism), in relation to diffusing chemical substances and odours (chemotropism), in relation to contact with surfaces (thigmotropism), and so on. In all cases the reaction is obligatory and the tendency of the reaction is to secure physiological equilibrium. As we ascend the scale of being, tropisms are often caught up along with more complex activities, but in many of the lower animals they can be studied more or less by themselves.

Some observations by Davenport Hooker on newly-hatched Loggerhead Turtles illustrate what is meant by an inborn tropism. The babies move away from red, orange, and green, but move towards transparent or opaque blue. It is probable, at any rate, that this helps them to reach the sea, which is their home, though they are born ashore. After entering the water they swim out to sea, perhaps attracted by the darker blue of the deeper water. In a large sand-pit, from which the ocean was

invisible, they did not move in any definite direction, and the control experiments showed that their behaviour was not affected by the sound or smell of the sea.

Differential Sensitiveness.—Associated with tropism, is the phenomenon of 'differential sensitiveness', to which Loeb and Bohn have attached great importance. An animal which is moving towards the light comes to a shadow; it may cross it, it may come to a standstill, it may recoil, but usually it tends to rotate through 180° and to proceed for a time in the opposite direction. The same phenomenon is observed in relation to gravity and chemicals diffusing in the water.

It is remarkable to see a tube-inhabiting worm in an aquarium instantaneously draw in its head and tentacles when one simply puts one's hand between it and the light. In the cells of these beautifully expanded filaments chemical processes were going on briskly and at a certain rate; by making a sudden shadow one makes a sudden change in the rate. The disturbance stimulates the sensory nerves, and a message travelling outwards again commands the muscles to contract. But it all happens so quickly—before one has time to say, 'Look at that!'

Differential sensitiveness is often mixed up in actual life with a tropism-reaction. Thus Bohn's experiments on starfishes led him to conclude that these brainless creatures are the slaves of diverse impulses, whose *combination* may be recognized in their behaviour. There is the impulse due to the immediately preceding state, there is the tropism-impulse, and there is the rotatory or oscillatory impulse. The result is an organic (not a deliberate) compromise, which Bohn says may be almost certainly predicted in given conditions. It cannot, however, be

compared to the composition of forces—this organic compromise—because so much depends on the physiological state of the creature at the time being.

Changes of Reaction dependent on Internal Conditions.—Modern experimenting has made clear that a creature's activity at a given time is, in part, dependent on the general physiological state of its body, apart from the activity of the central nervous system. And the physiological state of the body alters with functioning and environment. A well-known instance observed by Loeb is very striking. The caterpillars of *Porthesia chrysorrhœa*, which emerge from hibernation in spring, have a very pronounced attraction to light (positive phototropism). But when they have eaten, this disappears entirely, and does not reappear. The physiological state of the body has been thoroughly changed, and the behaviour likewise. Loeb also notes that when the male and female ants are approaching sexual maturity, they exhibit an intense and increasing attraction to the light, which the workers do not show. The physiological state of the body has been altered by the onset of reproductive maturity, and the behaviour is correspondingly changed.

After an animal has reacted many times in rapid succession to the same stimulus, it ceases to do so. Some active substance in the sensory cells, or in the nerve cells, or in the muscles, has been used up for the time being. The weak reactions before the substance was quite used up and before it has been properly restored have been put down to the creature remembering that it had been fooled these many times. But it is almost certain that this is quite wrong, and that there is no memory involved at all. Cellular memory begins when there is some more or less

lasting change or registration in the protoplasmic organization.

Changes of Reaction dependent on External Changes.—A small crustacean called Gammarus, very common in fresh water, where it plays the part of a cleaner-up, has the habit of avoiding the light. It frequents shaded corners and gets under things. To avoid using question-begging terms, we say that it is negatively heliotropic. Its habitual reaction or tropism is to move away from the light. But add the least trace of acid to the water, so that the solution is no stronger than $\frac{7}{10}\frac{2}{00}$ of one per cent., and Gammarus moves *towards* the light. It seems almost like magic, changing the creature's ingrained habit by a tiny drop—not of some potent philtre—but of commonplace acid!

This case would be extremely puzzling if it stood alone, but there are related facts which throw some light on it. Loeb has experimented with some smaller Crustaceans, Copepods, which do not seem in ordinary circumstances to be much affected by the light. When they are put into an aquarium lighted from one side only, they do not behave in any special way. But if some water rich in carbonic acid be poured slowly into the aquarium, the scene is changed. The Copepods become positively and strongly heliotropic; they form a group in the brightest part of the aquarium and dispose themselves, as best they can, in the direction of the light. Loeb suggests that the acid, acting as a catalyzer, increases the amount of the material affected by the light in the animal's eye from a previously minimal and negligible quantity to a quantity that cannot be disregarded. The difference between the more illumined and the less illumined side of the animal

becomes appreciable, and the animal arranges itself so as to secure chemical equilibrium, which doubtless spells comfort. In short, the addition of the acid has quantitatively increased the chemical effects of the light, so that it ceases to be negligible.

Rhythmic Movements.—The story of the little green Planarian worm, Convoluta, illustrates the combined effect of periodic external changes on the one hand and the internal rhythms of the body on the other. On the flat, sandy beach of some parts of Brittany, the small worms come up in crowds when the tide is out, and form green splashes on the surface. When the tide comes in they retire into the shelter of the sand. Their movements are synchronous with those of the tide. But Bohn has shown that the Convolutas in a quiet aquarium or in a glass tube behave in the same way; they ascend when the tide goes down, they descend when the tide comes in—though they are, of course, quite away from all influence of the tides. What is still more remarkable is that they keep time with the irregularities of the tide. Bohn believes that the alteration of the geotropism from plus to minus may be associated with the alternation of relative desiccation and relative hydration during the periods of low tide and high tide. In the case of hermit-crabs, however, Anna Drzewina observed that there was a rhythmic change from going towards the light at high tide and from the light at low tide, and that this occurred in an aquarium where they were covered with water all the time. It is very interesting to find that a rhythm established in relation to external periodicities persists in an aquarium where there is uniformity of conditions. A beautiful corroboration of the original dependence of the rhythm on the tides is found in the

fact that hermit-crabs from the Mediterranean, where there are no tides, did not show the change of tropism as regards light, but were always positively attracted to it. According to Bohn, a night and day rhythm has been to some extent established in the constitution of some sea-anemones, which go on for several days shutting during the day and opening at night, although they are kept in continued darkness.

There are internal rhythms in the body whose origin is obscure, e.g. in the secretory activity of the kidney, which is at its minimum at about 9 p.m. and at its maximum in the early hours of the day. Now, as Bohn says, we do not need to use psychical terms in referring to this, and why should we in connexion with the rhythms exhibited by shore animals in relation to the tides?

Establishment of Tropisms.—In many cases it is plain that animals improve by practice; the nerves and muscles become fitter by exercise; the creature finds itself. We see this in the individual; apart from any learning in the strict sense (by association, imitation, and inference), there is an apprenticeship of cells, tissues and organs, and a reward of increased efficiency. This is a matter of observed fact. What remains a subject of debate is whether the reward of individually increased efficiency is in any way entailed, or whether racial progress is wholly due to the selection of the fitter germinal variations. As the data stand at present, the verdict must, we think, be given in favour of the second interpretation.

Tropisms are hereditary compulsions to certain kinds of movement, and it is a thinkable theory that the particular combinations of them that occur in any particular animal express the result of a long process of selection. It is quite true that the tropisms often lead the animals to

their death, e.g. the moths to the candle, and that some (e.g. galvanotropism) are not known to be of use to their possessors, but there seems much evidence that the combination of tropisms normally exhibited by any particular living creature is well adapted to the ordinary conditions of its life. The particular combination is reasonably referred to the work of selection.

Beyond Tropism.—The question which one would like to be able to answer is, how far the conception of tropisms and the like suffices to cover what is observed of the ways of the lower animals. Is tropism all, or is there a gradual emergence of something more, which requires other formulæ? Is there the beginning of genuine behaviour? When a monkey's bonne-bouche is hidden in a vessel of a particular shape and colour, which is then placed among other vessels of other shapes and colour, the creature proceeds to look for it at random. But as the experiment is repeated and repeated, with due precautions, the monkey's tentative searches become fewer, till finally it goes straight for the proper vessel. In this method of trial and error the monkey doubtless uses its brains; is it possible that the same sort of method may be exhibited by animals which are very far from having any brains at all?

The experiments of Jennings are in favour of an affirmative answer. They go to show that some Infusorians practise in a simple way this method of trial and error, and thus make a step beyond tropisms. The Infusorian *Oxytricha fallax* was observed advancing towards a warm region of the water; it recoiled, turned slightly on itself, and advanced again. It met the warmth again and repeated the same reaction, altering the direction a little.

This happened four times without escape from the warmth. Eventually, however, after these trials, a way of escape was found. There are some who do not accept the interpretation that Jennings puts upon his facts; but every one admits that his facts are very important and that his interpretation must be given a fair hearing.

Professor Jennings has shown that the Protozoon Stentor, a relatively large Infusorian, reacts to a precipitation of powder in the water (1) by turning aside; or if that fails, by (2) reversing; or if that fails, by (3) contracting into its tube; or if the precipitation continues, by (4) shifting its quarters altogether. So far, trial of different reactions, three of which were ineffective, though in other circumstances any one might have been a perfectly good answer. But the point is that when Professor Jennings, after a short interval, repeated the fall of powder, the Stentor began with the fourth answer. It had learned something from its experience.

It remains, in part, a matter of opinion, but to us it seems impossible to describe the behaviour of Protozoa as merely due to tropisms. What they do is not always predictable, they seem to try different reactions, they seem to learn from experience, they show discrimination or selection in what they pursue and in what they avoid. Professor Jennings goes the length of saying: 'In no other group of organisms does the method of trial and error so completely dominate behaviour, perhaps, as in the Infusoria'.

The Study of Animal Instinct

There are few problems that have been more discussed than that presented by the instinctive behaviour of animals,

and it remains—in process of solution. Almost every modern observer admits that many of the activities of animals, say of bees and wasps, do not conform well with what we know as ordinary intelligent activities. The observed fact is that there is a different 'tang' about them. The problem is to define this difference, and it may be that one of the reasons why we find this so difficult is, that we are ourselves, predominantly, creatures of intelligence.

In early days the problem was not clearly focussed. The whole of animal behaviour was slumped, and the whole of human behaviour was slumped—two quite unscientific assumptions, and the problem was to find the difference between them. Of course, the man always got the best of it.

Thus, many of the Greek philosophers, such as Plato, fixed a great gulf betwixt the thinking man and the impulse-driven beast. Man had reason and intelligence, they said; the animal had sensations and impulses—only an *anima sensitiva*. It is very interesting to observe, however, that Aristotle, while ranking animal behaviour at a much lower level than man's, recognized clearly that it was purposive.

The conception of instinct, as Nature-implanted impulse, became a little more definite among the Stoics. They compared animals to little children who have not begun to think. Animals have sensations, perceptions, representations and impulses, they said, but no power of reasoning. They instanced the case of ducklings hatched and reared by a hen, which show an inborn, Nature-implanted impulse or instinct to make for the water. This was quite sound in its way, but we cannot help wondering what

they would have made of the case of a hen which, after several successive experiences of fostering ducklings, involving *inter alia* an anxious flight on to a stone in the middle of the pond, tried to lead her own *chicks* at a later date to the water!

In the Middle Ages and later, all animal activities were slumped together and ascribed to the 'faculty of instinct', and all human activities were, with equal futility, slumped, and referred to the 'faculty of reason'. Instinct was widely regarded as a divinely implanted capacity of doing purposelike things without understanding or even intending them. This vicious parenthesis of 'faculty psychology' led on to the extreme position of Descartes, who regarded animals as automatic machines, in whose workings the psychical substance plays no part. One must recognize that in this extraordinary view he had a clear perception of the strangely unplastic and stereotyped character of instinctive behaviour. But he did not realize at all that many animals are, apart from instinct altogether, very actively and acutely intelligent.

Through a number of notable men, and in different ways, a strong reaction set in against the Church view and the Schoolmen's view of animal instinct. It was pointed out that human activities could not be defined off in bulk as different in kind from animal activities. It was shown that some forms of animal behaviour could not be described except as intelligent, but that there was another kind of animal behaviour on somewhat different lines, which might be called instinctive. The reaction gradually led to the position of men like Büchner, who maintained that instinct was a term for the hereditary mental predispositions towards particular sequences of behaviour—predispositions

which were, of course, embodied in the particular inborn brain-pattern characteristic of the organism in question. He made the further step, which seems nowadays so obvious, of recognizing that in many animals instinctive behaviour predominates, while in others, as in Man, intelligent behaviour predominates. Thus it came to be no longer a question of animal behaviour in contrast to human behaviour, but of two different modes of behaviour, both of which may be illustrated in one creature, to wit, instinctive and intelligent.

Darwin's contribution comes next. With his characteristic common sense, he was quite clear that in animal behaviour we have often to do with individual experimenting and inference—in other words, with the exercise of intelligence, and often, also, with another kind of capacity —instinct—'implying some inherited modification of the brain'.

In the second place, taking cases like the instinct of the young cuckoo to tumble its foster-parents' offspring out of the nest, the instinct of the Ichneumon-fly larvæ to devour the soft body of the caterpillar in which they find themselves hatched, the instinct of the cat to play with the mouse, Darwin argued that they were not mysterious implantations, but *growths*, accumulated and perfected by Natural Selection. As to their origin, he agreed, on the one hand, with the Lamarckian school, that some of them might have arisen through the transmission of intelligently acquired habits; but, on the other hand, he laid most emphasis on Nature's sifting of the inborn variations which are continually cropping up. Variations in structure are of frequent occurrence, and so are variations in the responses that animals make to external stimuli. New

answers of a profitable kind—variations in reflex actions, for instance—become the beginnings of new instincts.

After Darwin came a period of critical discussion. The two chief theories of the origin of instincts were specialized and pitted against one another. Spencer, Haeckel, Preyer, and Wundt were prominent among the supporters of the Lamarckian interpretation—that instincts represent the inherited results of experience. A young pointer points because its ancestors were taught to point. An intelligently acquired familiarity with a certain sequence of actions ingrains itself, first, in the individual—as a habit, and, second, on the race—as an instinct, *the intelligence lapsing*. But other instincts, it was suggested, may have arisen from a lower level, namely from reflex actions, such as closing the eye on the approach of a missile, or the sucking of the babe when it is put to its mother's breast. If a series of reflexes occur often in a certain routine, they may become interlocked with a certain inevitableness, and the entailment of the results of the frequent repetition of such a sequence may give rise, so the theory ran, to an instinct. Both forms of the theory postulate the transmission of the results of experience, but on the first supposition the experience is intelligent, on the second it is simply reflex.

For many years the first form of the theory—that instinct represents lapsed intelligence—held the field, and it is certainly a very attractive interpretation. Intelligent activities, such as playing the piano, become by long practice habitual. They cease to require concentrated intelligent control; they suffer what is badly called mechanization; and the brain is left freer for something else. The intricate routine is somehow ingrained in the individual

memory; the theory is that in the course of generations the capacity of going through the routine is somehow ingrained in the germ-plasm, becoming part and parcel of the inheritance. On this attractive view, heredity is the racial analogue of memory, and development is a kind of recollection.

The next important step in the history was Weismann's critique of the transmission of acquired characters or modifications. These may be defined as individually acquired changes of bodily structure, which are directly due to changes or peculiarities either in function or in environment, and which so transcend the limits of organic elasticity that they persist after the inducing conditions have ceased to operate. That these are of common occurrence is a matter of everyday observation; that they are ever transmitted as such or in any representative degree has not yet been securely proved in a single instance. It is likely that biologists will return on a higher turn of the spiral to a recognition of the importance of 'Nurture' in evolution, but there cannot be any return to the crude belief in the transmission of individually acquired characters that was general before Weismann's criticism. It is very difficult to see, in connexion with habit for instance, how the establishment of a definite brain-track can representatively affect the germ-plasm, and unless it does that it cannot be transmitted. Thus, if Weismann's critique be sound, it forbids the assumption which is fundamental to the Lamarckian theory, that instincts are due to the inherited results of experience. Intellectual ability may be transmitted, for it is primarily due to a germinal variation in the direction of increased sagacity; but intellectual agility due to practice is not transmitted. Thus, Weismann

concluded that instincts owe their origin—not at all to experience or practice, either at the intelligent or the reflex level, but wholly and solely to the sifting of germinal variations. The pointing quality in pointers probably started with a constitutional variation in this direction (there are analogous cases among wild hunting animals). Man took advantage of this and strengthened it by vigorous selection, which still continues. Moreover, there is some individual apprenticeship still.

Many of Weismann's detailed criticisms must be kept in mind whatever conclusion is arrived at in regard to the nature of instinct. He referred, for instance, to the difficulty raised by those instinctive actions which occur only once in a lifetime, e.g. the young bird breaking its way out of the imprisoning egg-shell, the moth escaping out of an elaborate cocoon, the nuptial flight of the queen-bee, the gall-wasp laying its egg with such precision in the very heart of the bud of the wild rose, and so on through a long list. What is done only once in a life-time cannot become a habit!

Origin from Reflexes and Tropisms.—The result of Weismann's criticism was to concentrate attention on the idea of the origin of instincts as germinal variations. As this view presents difficulties to many minds, let us offer some illustration. Every now and then, though far too rarely, we hear some one say of a child, 'he has such peculiar ways of his own', or 'she is not like other girls'. That means a certain originality or idiosyncrasy, a new pattern; it is biologically regarded as the expression of a germinal variation. It really represents, we make bold to say, an experiment in self-expression on the part of the creative germ-plasm.

Now these germinal variations, whose origin is another story, find expression at all levels. A person may be born with a *chemical* variation of such a sort that even a small quantity of egg in his food acts like a poison. Another may be born with some variation in the eye which leads to short-sightedness, colour-blindness, night-blindness, or the like. Another has a quite unusual sense of locality or direction. Another is a musical genius. In short, organisms may be born with all manner of constitutional variations which lead them to respond in an unusual manner to external stimuli. The theory of instinct to which Weismannism, for instance, leads, is that instincts arise from within as germinal variations, that those which are profitable survive, while those that are very disadvantageous (like some reversionary instincts in man) lead to the death of their possessor. Instincts, as M. Marquet has well said, are 'inborn inspirations'. Their origin is confessedly obscure—from within the creative germ-plasm—but not any more obscure than that of many other inborn variations, such as any form of genius, or any novel departure in detailed structure.

Experiments on Instinct.—The next step was the establishment of the experimental study of instinctive behaviour, which we may associate in particular with the name of Lloyd Morgan. Spalding had indeed followed the same method many years before, but his observations were somewhat lacking in exactness. What Lloyd Morgan did was to incubate the eggs of fowls and some other birds in the laboratory, so that he could study the behaviour of the young away from any influence of parental education. He was in this way able to demonstrate the instinctive character of some capacities, such as uttering a character-

istic call-note or swimming deftly a short time after birth (in the case of coots). In the case of the young water-hen he showed that the capacity of diving and swimming under water was also thoroughly instinctive, but might be deferred in its expression for a long time until the appropriate liberating stimulus pulled the trigger. Very instructive was his demonstration of the striking absence of instincts that one might have expected to be present. Thus, the young chicks to whom he was foster-parent showed no recognition of water as drinkable material, though they would take drops eagerly from a finger touching their bill. They only became aware of water as water after they happened to wet their bills by pecking their toes when standing in a dish. Then they immediately drank in the usual fashion. The chicks had never seen their mother, of course; but it was perhaps a little surprising that they paid no special attention to her clucking outside the door. For one might expect innate awareness of the significance of a particularly important sound, since we know that the capacity of producing a certain call-note is in some cases innate or instinctive. Professor Lloyd Morgan also found that his chicks were sometimes innocent enough to stuff their crops with worms of red worsted, but they soon knew better. For, the important outcome of the investigations was that the chicks make up for their paucity of instincts by their quick intelligence—by their extremely rapid educability.

Lloyd Morgan worked out an admirable definition :—

'Instincts are congenital, adaptive and co-ordinated activities of relative complexity, and involving the behaviour of the organism as a whole. They are similarly performed by all like members of the same more or less

restricted group, under circumstances which are either of frequent recurrence or are vitally essential to the continuance of the race. They are to be distinguished from habits which owe their definiteness to individual acquisition and the repetition of individual performance'.

Lloyd Morgan's work marks a distinct stage in the study of instinct. The experimental method, as usual, makes a new beginning. His work has been continued, but only continued by other investigators. And, leaving aside entirely some important experiments on animal *intelligence*, we may say, as regards the history of the investigation of instinct, that the two new steps of importance are concerned with (*a*) the endeavour of Loeb, Bohn and others to analyse particular cases of instinctive behaviour into combinations of tropisms and the like, and (*b*) the suggestion of Bergson that instinct expresses a particular mode of knowledge, differing from intelligence rather in kind than in degree.

Instances of Instinctive Behaviour

When we pass in the Animal Kingdom from brainless types, like polyps and starfishes, to creatures of higher degree, like crabs and ants and spiders, we find ourselves in a new world. There are tropisms still, and there is differential sensitiveness, but there is a new kind of behaviour much more complicated, which is called *instinctive*.

When a shore-crab is carried over the beach and then laid down, it makes for the sea in its own peculiar sideways fashion. Light and wind and slope seem to have no effect; it makes for the moisture of the sea. This is probably a tropism, perhaps complicated by some higher capacity.

When a worker-bee, coming out of the hive for the first

time, flies to a flower which it has never seen before, and tackles it deftly, collecting pollen and nectar, it illustrates instinctive behaviour. We say that it does its work 'as if to the manner born'; and it is characteristic of instinctive capacity that it is hereditarily entailed.

An unhatched lapwing may be heard saying 'pee-wit' from within the egg. This is its distinctive call-note, and its utterance appears to be instinctive—quite independent of instruction or imitation. Chicks reared in an incubator have the usual vocabulary. This, again, is characteristic of instinctive behaviour, that it does not require education or example or practice, though it may be improved thereby. As Dr. Hans Driesch has said, instinctive behaviour is 'a complicated reaction that is perfect the very first time.'

The mother Sphex-wasp, whose behaviour we shall afterwards discuss, stocks each of the cells in her nest with three or four paralysed crickets. On the under side of one of these (turned on its back) she fixes an egg, out of which in three or four days a delicate worm-like larva is hatched. This tiny creature bores a hole through the cricket's cuticle, makes its way into the paralysed body, and proceeds to devour the tissues. In a week or so, having attained a length of twelve millimetres, it goes out by the aperture by which it entered, and proceeds to enjoy another cricket. In about twelve days it has eaten all its larder. Its behaviour is strikingly instinctive.

The way in which some new-born mammals immediately proceed to suck their mother illustrates an instinctive endowment. 'Each little pig the moment that he is outside hurries over the sow's hind legs, and, in the second second of his outdoor life, has a teat in his mouth'. Newly-born pigs also show instinctive knowledge of the significance

of the sow's grunting. Spalding put a young pig into a bag the moment it was born, kept it in the dark for seven hours, and then placed it near the sty, ten feet from where the sow lay concealed.

'The pig soon recognized the low grunting of its mother, went along outside the sty, struggling to get under or over the lower bar. At the end of five minutes it succeeded in forcing itself through under the bar at one of the few places where that was possible. No sooner in, than it went without a pause into the pig-house to its mother, and was at once like the others in its behaviour'.

A blind-folded youngster found its mother almost as well as one with its eyes free. After two days blindfolding it required only ten minutes' practice to make it 'scarcely distinguishable from one that had had sight all along'.

In the strict sense, birds do not *learn* to fly, though their inborn capacity of flying is improved by exercise. Spalding put five unfledged swallows in a small box with a wire front, and hung it near the nest. The parents fed the offspring through the wires, and the young birds throve as usual, though one was found dead just as it became fully fledged. The others were set free one after another. Two of them were perceptibly wavering and unsteady, and two were more effective from the first. But even the less endowed flew ninety yards right away, and none of them knocked against anything. In a subsequent experiment one of the newly-fledged, newly-liberated birds performed almost at once magnificent evolutions over the beech trees. All this was performance without practice, for the swallows had not been able even to extend their wings in their narrow prison.

In the familiar case of the spider's web, there is no

evidence that the spinner improves by practice. The first web made by the spiderling has all the parts seen in the web made by the adult. Montgomery has shown, in species of *Epeira*, that as the spiders grow older the thread becomes thicker and the web larger; there are a few more radial rays and a few more loops in the spiral, but these differences are correlated with the increased weight of the spider and the increased size of the spin-

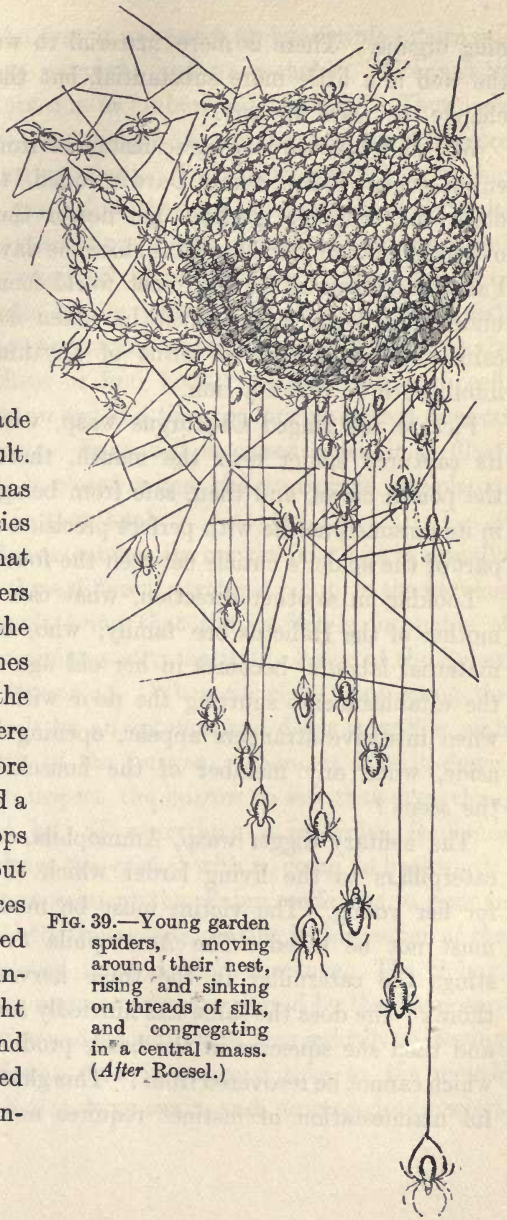


FIG. 39.—Young garden spiders, moving around their nest, rising and sinking on threads of silk, and congregating in a central mass. (*After* Roesel.)

ning organs. There is more material to work with, and the web is a little more substantial, but there is no real change, or need for any.

We shall take two or three instances from the veteran entomologist, Fabre, whom Darwin called 'that inimitable observer', who has perhaps got nearer the intimate life of insects than any one has done since the days of Réaumur. Fabre sees Instinct in the insect world looming as a big, underivable fact, which must be taken *as given*, which cannot be explained in terms of anything else, either intelligence or reflex action.

Picture the ringed Calicurgus wasp, which first stings its captured spider near the mouth, thereby paralysing the poison claws, and then, safe from being bitten, drives in its poisoned needle with perfect precision at the thinnest part of the spider's cuticle between the fourth pair of legs.

Looking in another direction, what can we say of the mother of the Halictus bee family, who, after prolonged maternal labours, becomes in her old age the portress of the establishment, shutting the door with her bald head when intrusive strangers appear, opening it, by drawing aside, when any member of the household arrives on the scene?

The solitary digger wasp, Ammophila, is wont to drag caterpillars to the living larder which she accumulates for her young. The victim must be made inert, but it must not be killed. The Ammophila first and quickly stings the caterpillar in the three nerve-centres of the thorax; she does the same less hurriedly for the abdomen; and then she squeezes in the head, producing a paralysis which cannot be recovered from! This ghastly but wonderful manifestation of instinct requires no noviciate, it is

perfect from the first, it expresses an irresistible inborn impulsion, at once untaught and unteachable. The insect's achievements are due to 'inborn inspirations'. They look like intelligence; but disturb the routine, and the difference becomes at once apparent. To instinct everything within the routine is easy; but the least step outside is difficult.

It is many years since Fabre described the behaviour of the Sphex wasp (*S. flavipennis* or *S. maxillosus*) in stocking a larder for its young. It makes burrows, each consisting of a horizontal porch, a sloping main shaft, and off this three or four horizontal cells. In each cell, the wasp places an egg and three or four paralysed crickets or related insects. Each cell is closed when it is filled, and the shaft is closed when the storing is completed. Another shaft is then sunk.

When the Sphex catches its cricket it stings it, usually three times, in three different strategic points in the nervous system, the result being that the cricket is incapable of movement, but remains alive until the larvæ of the Sphex are ready to devour it. When the Sphex has stung the cricket, it grips it by an antenna and drags it or flies with it to the mouth of the burrow. There it lays it down, and proceeds to inspect the burrow to see that everything is as it should be. If everything is in order, it comes up again, and drags the cricket with it, going in backwards. The interesting experiment that Fabre made was to remove the cricket while the Sphex was making its inspection of the burrow. He placed it at a short distance. The Sphex, coming up again, was apparently agitated by the disappearance of its captive and sought for it energetically. Having found it, the Sphex drew it a second time to the mouth of the burrow, laid it down again, and proceeded to inspect

afresh! This routine was repeated no fewer than forty times in succession, and the apparent compulsion to do things always in a given order is evidently strong. Although the burrow had been so often inspected, the Sphex had to do it again, when it brought its captive cricket once more to the entrance.

In regard to a nearly-related East Indian wasp, Rothney made a similar experiment, which is summarized by Dr. Sharp (*Cambridge Natural History*, vol. 6, p. 110).

'He discovered a nest in process of construction, and during the absence of the mother-wasp abstracted from the burrow a large field-cricket that she had placed in it; he then deposited the Orthopteron near the cell. The parent Sphex, on returning to work, entered the tunnel and found the provision placed therein had disappeared. She came out in a state of excitement, looked for the missing cricket, soon discovered it, submitted it to the process of malaxation or kneading, and again placed it in the nest, after having cleared it from some ants that had commenced to infest it. She then disappeared, and Rothney repeated the experiment. In due course the same series of operations was performed, and was repeated many times, the Sphex evidently acting in each case as if either the cricket had disappeared owing to its being incompletely stunned or to its having been stolen by ants. Finally, the observer placed the cricket at a greater distance from the nest, when it recovered from the ill-treatment it had received sufficiently to make its escape. The points of interest in this account are the fact that the cricket was only temporarily paralysed, and that the wasp was quite able to cope with the two special difficulties that must frequently occur to the species in its usual round of occupations'.

Fabre's experiment certainly shows how thoroughly

an instinctive animal may become the slave of routine. On the other hand, there are details in the story which suggest that the routine is no blind automatism. There was the energetic searching for the stolen cricket—a variation from the usual routine. It seems pushing the law of parsimony too far to suggest that the search was simply the fussing about of a perplexed wasp. There was, moreover, an incidental experiment made by Fabre. On one occasion he substituted for the paralysed cricket another specimen which had not been stung. When the Sphex came to drag it in, the cricket naturally resisted, and there was a keen struggle. It did not last long, however, for the Sphex soon leaped on its victim and stung it thrice. It is possible that intelligence took the reins at the critical moment. In any case, there was no automatism.

Fabre has led many to marvel at the effective way in which the Sphex wasp stings the cricket in its ganglia, and drags the paralysed victim to the burrow, and this marvel does not stand alone. But Marchal points out that the instinct is not so fixed or perfect as Fabre represented. Mistakes are sometimes made; the precision of the fatal thrust is sometimes at fault; many blows are often given. The spots where the Cerceris strikes the Halictus are those most conveniently reached by the sting; the squeezing of the brain is because the Cerceris likes the juice; and the idea that the mother Bee-hunter empties the dead bee of its honey because that would give the carnivorous larvæ pains in their stomach is altogether too anthropomorphic (see p. 426).

The Tale of the Black 'White Ant'

Among quaint and wonderful insects a unique place must be ceded to the so-called 'white ants' or Termites.

They are not related to the true ants, differing widely from them in structure, in life-history, and in their social economy, but they resemble them in their achievements and in compelling our admiration. They are unique among insects in often contributing to the scenery of the lands which they inhabit, for the hills or termitaries many of them construct out of masticated earth are often twice a man's height and are often as thick as mole-hills on a badly infested field. Indeed there are many parts of South Africa where the hard domes of the termitaries form perhaps the most prominent feature in a monotonous landscape. Like the true ants, they are 'lords of the sub-soil', but their appetite for woody stuffs gives them a wider grip of things, and their influence on human life is very considerable. Telegraph posts and the like have to be made of iron to resist their jaws; the legs of the table have to be insulated on earthenware cups; and, as the late Professor Henry Drummond said, there are many places where it is dangerous for a man with a wooden leg to go to sleep without taking special precautions, else his artificial member will be a heap of sawdust in the morning. We must not even begin to discuss the work they do in pruning forest trees of their decaying branches, and in aiding the earthworms in the circulation of the soil—literally making the world go round. For as they greatly

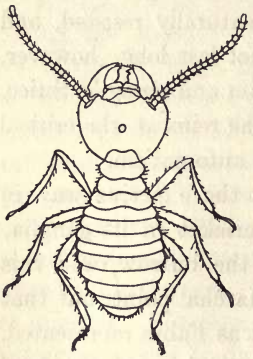


Fig. 40.—Worker Termite, *Termes ceylonicus*; enlarged. (*After* Bugnion.)

dislike the light, almost without exception, they build earthen tunnels as they go, and the substance of these is sooner or later weathered down, and is carried by the rain to the streams and thence to swell the alluvium of the distant valley.

Another introductory note is necessary before we pass to consider, as a particular illustration of instinctive behaviour, the ways of the Black Termite. A little must be said of the Termites' social economy. There is a striking division of labour. Besides the males and 'queens', that is to say, the parental members of the community, there are, in many cases, supplementary 'kings and queens', kept in reserve and ready to replace the others in the event of emergency. Then there is the great body of 'workers', who are really permanent children of both sexes, non-reproductive individuals who do not grow up. They differ therefore from the 'workers' in the bee-hive or the ant-hill, who are all females, though they remain in normal circumstances non-parental. Finally, besides the workers in the Termite community there are often big-jawed soldiers, likewise non-parental, and the intricate division of labour does not end here. But let us turn to the tale of the black Termite of Ceylon, the Black 'White Ant' as who should say—a tale which we owe especially to the patient observations of Professor Escherich of Tharandt and Professor Bugnion of Lausanne.

The Black Termite, so abundant in Ceylon, is certainly peculiar. It is more like a true ant than a Termite. It resembles the black wood-ant (Lasius fuliginosus) in colour, in many of its ways, in its nest, and even in its smell. The nest is usually in a hollow stem—a labyrinth of passages hollowed out in a brown or black wood-paper. When

the observer opens a nest, ' there streams out a very flood of black creatures, soldiers and workers, covering his hands, but doing him no harm.' Some of the workers are trying to save the babies—who are not of course theirs—by carrying them in their mouths. Sometimes a white baby is seen sticking on to the big head of a soldier.

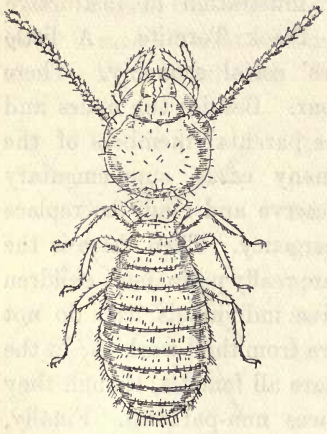


Fig. 41.—Worker Termite, *Termes convulsionarius*; enlarged. (*After* Bugnion and Popoff.)

Familiarity can surely never breed contempt at the spectacle of a Black Termite army on the march through the jungle, moving quickly in a twisting file, it may be several hundred yards long, or four inches across, pressing through and round and over a multitude of obstacles, hurrying on hour after hour, at the rate of about a yard in a minute, making tortuously for a definite end—a tree covered with lichens where they find their food supply. We speak of an ' army ', but most of the marching Termites are ' workers ', the soldiers are posted on each side of the file and often move very little. The wonder of the spectacle increases when it is discovered that through the whole army—among soldiers and workers alike—there is no vision at all. The effective march of the blind army depends wholly on exquisite senses of touch and smell, which appear to be located in the antennæ or feelers.

Professor Bugnion found a convenient small colony of

the Black Termite in the hollow stem of a Pandanus, and was able to transport it intact to his hut, where it was placed on a table. The very first night the black army made a sortie, descending a table-leg, and visiting a cocoa-tree about three yards off. They returned in the morning, and some of them carried a little greyish yellow lichen in their mouths. The next event was an invasion of the Termite nest by a band of true ants (Pheidologeton) whose soldiers have particularly big heads. These proceeded to carry off the Termite larvæ, and in spite of valiant resistance would have succeeded had not M. Bugnion played the part of providence. He drove away the intruders and put the Termite nest in a more secure place. When night fell the blind army made another sortie, the details of which were interesting. The workers came out tentatively, guarded by lines of soldiers; after going a little way some turned back again, as if to instruct the main body; they got on to the track of the night before, which was marked by traces visible to M. Bugnion and probably smellable to the Termites. But after all, the sortie was a failure; they did not find the cocoa-trees.

The observer formed a little bridge over a deterrent difficulty, and next day the cocoa-tree with its lichens was covered by innumerable workers. They went about their business in groups, five or six grated off the lichen and passed it to a carrier, who continued to collect till he had as big a packet as his mouth would hold. But the return was concerted and orderly, not individual or haphazard. It did not begin until the soldiers, who had been standing all the while at attention, gave a signal. After a little moving to and fro, the workers formed into line, descended the tree, and made for home in two great bands.

The so-called 'soldiers' play a very important rôle as guides and scouts. When Escherich broke a march by making a little gully with his finger, there was general disorganization in the ranks behind the interruption, and the spectacle was seen of the soldiers exerting themselves to the utmost to restore order and the broken connexion. They are also scouts, searching out new lines for foraging. 'Very carefully, step by step, just like cats, they slink forwards, one behind the other, and if the foremost detects anything the least suspicious, he draws nervously back, pulling his "brave" comrades after him.'

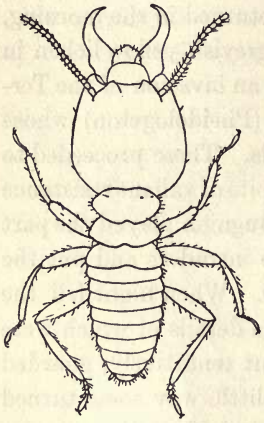


FIG. 42.—Soldier Termite, *Termes convulsionarius*; enlarged. (*After* Bugnion and Popoff.)

Professor Bugnion acted as war-correspondent to the black army from December 18 till March 8, and the story of the goings out and comings in is of great interest to the serious student of animal behaviour. We cannot do more than refer to a few of the observations. The importation of a second colony led to a war which lasted for three days, after which a peace was concluded, and the first colony (which had no queen and only a few children) joined the second. An excursion was made every day; fifteen cocoa-trees were visited, some at a distance of 15–20 yards; five roads were established, which were carefully adhered to. Occasionally, however, the whole army got lost, failing to find the track after they left the tree, and long detours

were sometimes made before they got right again. The sortie usually began about sun-down (6 p.m.), but earlier if it was a dull afternoon; there seemed always to be hesitation and caution at first; a number of soldiers acted as scouts, discovering the best tree; and there was always that turning back of certain individuals who kept the main body in touch with the advance guard. The orders seemed to be given through the antennæ or by a quivering of the whole body. The retreat usually began at dawn and lasted for four or five hours. Escherich notes that most of the return journeys ended about nine or ten o'clock in the morning. Photographs of the sortie (taken by magnesium flashlight) and of the retreat (taken in daylight) showed that the long troop of workers marched between two lines of soldiers who kept their heads turned outwards.

As to numbers, Escherich computed that a vigorous band, crowding past at the rate of about 600 in a minute, would comprise about 200,000 individuals. Professor Bugnion counted about a thousand to a yard, and as the army took five hours to file past at the rate of a yard per minute, there must have been about 300,000 individuals. There were over two hundred soldiers to every thousand workers. Professor Escherich has shown that the number of soldiers guarding a march varies greatly with the danger. When the risks are great the soldiers stand within an antenna-length of one another so that they are always in touch. One morning the returning troop was harassed by the little true ant previously mentioned. Professor Bugnion counted two hundred soldiers on a length of four feet forming at a critical point a living wall covering the retreat of the black workers. It may be noted that the species here dealt with does not eat wood, but subsists

almost wholly on lichens, occasionally adding particles of rotting leaf and something out of the damp black soil. Professor Escherich watched them grazing like so many cows on a meadow of green unicellular Algæ growing, as we often see in this country, on damp stones. Occasionally the same observer saw a few workers eating up every shred of a deceased comrade.

Escherich was greatly impressed by the cleanliness of the Black Termites. Like cats, they spend a good deal of time over their toilet, and they lick one another all over, washing every crevice of their many-hinged bodies. Their mutual aid in this direction reminded him often of monkeys. Care is taken to keep the nests very clean, and the refuse is disposed of in a scrupulously tidy way. The keen-eyed observer goes the length of suggesting that there are special sanitary inspectors. It certainly looks very like it.

Some of the trees visited by the Black Termites bear the nests of a well-known tailor-ant, Oecophylla, which is three times bigger than our Termite and much more agile. When the Termites arrived there was of course a bitter battle, in which the true ants almost always got the worst of it. Escherich occasionally saw the soldiers lose their presence of mind and fall back on the workers, among whom a temporary panic resulted. The soldiers have big heads, but very small jaws, and the puzzle is how they can fight at all. Their tactics are nothing short of extraordinary. When the Oecophyllas draw near, the Termites squirt full in their face drops of a viscous secretion which appears to drive the true ants almost crazy. They drop to the ground and continue for a long time rubbing their faces against stones and debris. The Termite soldiers resume

their attitude of detached immobility and the workers go on with their lichen-gathering.

It may be safely said that the recent observations on the Black Termite have given the student of animal behaviour some material of unsurpassed interest and have raised some deep problems. Perhaps their chief general interest is in their illustration of somewhat complex social life on an instinctive basis, and in their corroboration of the view that instinct and intelligence are expressions of life on quite divergent tacks of evolution, differing rather in kind than in degree. But on any interpretation the Black ' White Ant ' is passing wonderful.

Specialized Character of many Instincts

One of the striking facts in regard to instincts is that they are *often* highly specialized, and that their value depends on their precision. Let us give two or three examples. It is well known that the young cuckoo, while still blind and naked, will eject the rightful tenants of the nest with great effectiveness, just as if it understood all about it. It is helped to get rid of the eggs by a hollow on its back, which persists for eleven days or so. A careful observer of the ejection of a partly-fledged young pipit from a nest below a heather-bush on the declivity of a low, abrupt bank has called attention to the purpose-like way in which ' the *blind* little monster made for the *open* side of the nest, the only part where it could throw its burthen down the bank '.

The specific character of instinct is finely illustrated by the solitary wasps, which store food in their nests for the future grubs. In most cases each species of wasp has her

own particular kind of prey, which she knows instinctively; in most cases she handles her prey in a quite distinctive way; in most cases she has a particular routine when she arrives at her nest. The behaviour is complex, adaptive, specific and constant. There is hereditary awareness of certain things (a cognitive disposition), and there is linked to that a hereditary impulsion to a certain routine (a conative disposition). As Dr. McDougall puts it:—

'The structure of the mind of such an animal must be conceived as consisting of a limited number of innate cognitive dispositions, each linked with a conative disposition; and the maintenance of the single cycle of activities, which compose the life history of the adult creature, depends on the fact that the exercise of each conative disposition produces a situation which excites another cognitive disposition, which in turn sets to work another conative disposition, and so on, until the cycle is completed'.

Professor Lloyd Morgan relates his instructive experience with a young moorhen which he had hatched in an incubator. It swam well, but it would not dive. One day, however, when it was swimming in a pool it was suddenly frightened by a boisterous puppy. 'In a moment the moorhen dived, disappeared from view, and soon partially reappeared, his head just peeping above the water beneath the overhanging bank'. Suddenly, and without warning, it had exhibited a characteristic piece of behaviour, and its dive was absolutely true to type. The diving performance was obviously something novel and specific; it did not grow out of the swimming on the surface.

The method of self-delivery practised by the unhatched chick within the egg used to be regarded as a sort of appren-

ticeship to the future pecking. But it is quite different. As Spalding observed:—

'Instead of striking forward and downward (a movement impossible on the part of a bird packed in shell with its head under its wing), it breaks its way out by vigorously jerking its head upward, while it turns round within the shell, which is cut in two—chipped round in a perfect circle some distance from the great end'.

At the time of hatching there is an exaggeration of a special muscle which afterwards ceases to be conspicuous!

Some of the cases of so-called instinctive reaction are so strikingly specific, so definitely related to particular circumstances, that one is certainly prejudiced, at first sight, in favour of the view that the lessons of experience are in some way entailed. Professor Semon cites such a case from Lenz's *Schlangen und Schlangenfeinde* (Gotha, 1870)—a very reliable work. Lenz took two young buzzards from the nest and reared them. They killed slow-worms and ringed snakes carelessly, but they were in a most striking way excited when they first had to deal with an adder. They had previously devoured pieces of adder's flesh quite greedily, so it could not be smell that pulled the trigger of the instinctive excitement. Moreover, buzzards work by sight. The question then is, What was it that made the buzzards treat the adder in a way entirely different from that in which they dealt with grass snakes? The same kind of fact was brought out by the experiments made in the London 'Zoo', of confronting various types of mammals with venomous snakes. None paid any attention to the apparition except monkeys, who showed unmistakable symptoms of great fear. It is probable

enough that these inborn antipathies of higher Vertebrates are ingrained at a higher level of the brain than instincts are.

An exceedingly interesting inquiry has been well begun by Dr. Louis Robinson in his *Wild Traits in Tame Animals* (1897)—an inquiry into those modes of behaviour which seem to be survivals of the original wild life. It was in the pack that the dog organically learned to signal by its tail, to guard its bone, to obey orders, to watch, and so on. As Darwin suggested, the turning round and round on the hearthrug may be connected with the primitive roving of the pack, which moved from place to place and found temporary resting-places for the night among the long grass. The crime of sheep-worrying is a recrudescence of old ways. Shying in horses may be in part a relic of a valuable ancestral instinct to swerve suddenly from suspicious movements of snake or wild boar or crouching tiger among the bushes and reeds. Wild foals run with their mothers, and unto this day they do not gorge themselves with milk, as calves do. Scotch cattle, taken to a large American ranch, hid their calves among the thick herbage, true to the old ways, for the wild cows hide their young in the thickets while they go to graze in the open. The angry ewe still stamps her foot—the old signalling of danger on the mountain side. We laugh at the sheep as they go in file and jump in succession over an imaginary obstacle simply because one of them did it by mistake, but they are acting in accordance with one of their oldest and most useful instincts. The pigs squeal now because their wild ancestors squealed to summon their neighbours to help them against a bear; they grunt now because it was by grunting that their ancestors kept together in the jungle or among the high

bracken. This and that interpretation may be fallacious, but there is no doubt as to the profitable nature of the inquiry.

Limitations of Instinct

Wonderful as instinctive achievements are, they are much more limited than those of intelligence. They are tied down to particular forms and sequences, and even a slight change or dislocation makes them futile. A good example of this limitation of instinct is given by Fabre, who states that when the nest of the common wasp is covered with a bell glass, the imprisoned insects never dig a passage out, though they could if they tried, but remain cooped up till they die. Moreover, although stragglers which had been left outside will actually dig their way in, they have not wit enough to show their fellows the way out, nor even to make their own escape again. Instinct is always fatalistic.

The mason bee makes a mortar nest with a lid, through which, at the proper time, the grub cuts its way. Put on a little paper cap in actual contact with the lid, and the grub has no difficulty in cutting through the extra layer. But if the covering cap be fixed on just a little way above the natural lid, not in contact with it, the grub emerging into the closed interval between the lid it has cut through and the artificial covering cap, can do no more, and dies. It could cut its way through with the greatest of ease, but it cannot. For when it has emerged through the first lid it has done all its cutting, and it cannot repeat it. So, the routine having been disturbed, it dies in its paper prison, for lack of the least glimmer of intelligence.

Similarly, when Fabre wickedly joined the front end of a file of procession caterpillars to the hind end, they went on circling round and round the stone curb of a big vase in the garden, day after day for a week, covering persistently many futile metres. As Fabre said: 'Ils ne savent rien de rien'.

Alfred G. Mayer and Caroline G. Soule made some interesting experiments on the caterpillars of the milk-weed butterfly (*Danais plexippus*). Thus they observed that once the caterpillars have started eating, they may be induced to eat substances which they would never have begun with. Although they are not receiving the proper stimulus, they cannot stop. This tendency to continue activity 'in the face of a non-stimulus' is called 'the momentum of the reaction'. Another interesting point is the shortness of their associative memory. If a 'distasteful' leaf is presented at intervals of one and a half minutes, the caterpillar tries it every time and takes about the same number of tentative bites. But if the leaf be presented at intervals of about thirty seconds, the caterpillar takes fewer and fewer bites, and then refuses. But it cannot remember for a minute and a half.

The limitations of instincts are very interesting, especially in showing how different instinctive behaviour is from intelligent behaviour, but it must be emphasized that it is part of the conception of an instinct that it shall be serviceable from the start. To a greater or less extent it must be serviceable for survival in the widest sense, and serviceable also 'as affording the congenital foundations for an improved superstructure of behaviour'. Even though it is far from perfect, even though it is afterwards greatly improved, even though it is only a play instinct (which is far

from being a mere luxury)—an instinct is always serviceable.

That animals are sometimes led astray by 'following their instincts', is well known; the birds who act as a cuckoo's foster-parents illustrate this. That the hereditary endowment is often insufficient for every emergency, is also well known; thus cattle will sometimes eat poisonous herbs. But there is no difficulty here, since, on the whole, creatures are well served by their instincts. It is impossible that all instincts should be perfect in animals whose environment is changeful or who change their environment.

The Norwegian lemmings, when they form migratory bands, often head westwards, and continue on their way with great persistence and considerable pugnacity. They swim across lakes, but are apt to lose their bearings in the water and drown. As they march, their ranks are thinned by birds of prey and small carnivores; even the reindeer trample them underfoot. It is often but a small percentage that reach the shores of the North Sea—a select band of survivors deserving a better fate. For, true to their instinct to go on, they swim into the sea and are drowned. In a case vouched for by Collett, a vessel sailed for fifteen minutes through a swarm, the water being alive with them as far as the eye could reach. What must be noted in a case like this, is, that the go-ahead instinct is often serviceable, though it cannot avail against a famine or the occurrence of seas on the earth's surface.

The instinct to *go on* is very strong in eels, and its general effectiveness is manifest. It carries them over difficulties and unfavourable conditions if these are not too long drawn out. It can hardly be urged as an imperfection that these persistent creatures, both as elvers and afterwards,

work their way into fatal culs-de-sac. Mr. W. L. Bishop reports that in the water-works of Dartmouth, Nova Scotia, eels caused considerable trouble by continually getting into the water-mains, and blocking the service-pipes.

Some Difficult Phenomena

'Feigning Death'. It is well known that many Crustaceans and Insects become absolutely motionless when suddenly disturbed. There they lie, without moving a feeler or a limb, as if they were dead. This may be very useful when they are being hunted by enemies who only snap at moving things, who perhaps do not see them unless they move. The phenomenon is very familiar and very puzzling. Whether it is a physiological faint or an instinctive feint, who can tell us. But it is admitted by all that in the lower animals it is not a deliberate 'playing 'possum' and that it is not a 'fear paralysis'.

Bohn deals with the so-called 'feigning death' by pointing out that it comes into line with 'differential sensitiveness', which is exhibited by some of the lower animals in face of a sudden change in the environment. Single-celled animals and tube-inhabiting worms show it equally well; they retract and remain quiet; the duration of their passivity varies with the light and temperature; after several experiences in succession the reaction dwindles away. There is a strong suggestion here of the so-called 'death-feigning' in insects and crustaceans, which follows all sorts of stimuli, which varies in its duration with the temperature and the illumination, which wanes after it has been brought on repeatedly. The creature passes into a strange

state; one limb may be cut off after another, and it gives not the slightest reaction. As Darwin noted, the attitude is often not at all like the death-attitude. The phenomenon may be exhibited by a decapitated insect. There seems reason, then, to agree with Bohn that in Crustaceans and Insects the so-called death-feigning is an exaggeration of the 'differential sensitiveness' of simpler animals.

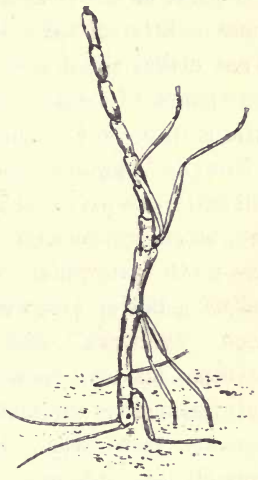


FIG. 43.—An insect—Carassius—standing on its head in the 'cataleptic' or 'death-feigning' state. A little less than natural size. (*After* Schmidt.)

In the water-insect known as the water-scorpion (*Ranatra*), there is a marked 'death-feigning', but it is exhibited only in the air, which the American species, at any rate, rarely visits. It is so pronounced, both in young and adult forms, that the creature can be cut in two without any response, but it is difficult to see that it can be of any value. Mr. S. J. Holmes writes:—

'One is strongly inclined to believe that the death-feint, which is manifested only when the insect is in the air, is rather an incidental result of certain physiological peculiarities of the organism than an instinct which has been built up by Natural Selection for the benefit of the species'.

'**Bluffing**'.—Every one knows how the cat that is chased by an impudent dog suddenly turns and 'stands

at bay', a very picture of wrath, with its teeth showing and its fur all on end. Some have supposed that the cat makes itself look bigger and that the dog is abashed by the sudden change of dimensions. But the idea that there is deliberate 'bluffing' cannot be considered, even with a creature as clever as a cat. The cat is angry, and sometimes a little afraid; the raising of the fur is a reflex. What makes the dog slink off is partly the abruptness of the change of tactics and partly the awareness that this little spitfire 'means business'.

Now, if 'bluffing' does not take place in the cat, it is still less likely to occur among the lower animals. Therefore, when we observe the 'terrifying attitude' of the puss-moth caterpillar, or the Eyed Blenny (*Blennius ocellaris*), raising and waving its dorsal fin with its curious black 'eye-mark' when it is attacked, or the Russian tarantula taking a pose which makes it look biggest and most impressive, we must not too hastily conclude that the creatures know what they are doing. What we see is probably an inherited reflex, and is probably of real utility in the struggle for existence, for it does appear to have a disconcerting effect on enemies.

'Homing'.—It is well known that ants can find their way home from a distance. The present-day interpretation does not postulate any special 'homing instinct', but regards the phenomenon as due to a combination of factors. There seems no doubt that use may be made of odoriferous substances left on the track, and Bethe started the hypothesis that there is a quantitative or qualitative difference between the scent on the way from the nest and that on the way to the nest.

The results of Turner's experiments (1907), led him to

conclude that the ants *learn* to find their way. They make many mistakes at first, but gradually improve. They associate different impressions (olfactory, tactile, visual, etc.), and remember certain finger-posts. According to some, there is a 'muscular memory' of the movements effected and of the amount of work done. But the general view is that the homing of ants is the result of the practised combination of a number of hints. According to Pieron, the way-finding of ants is most frequently due to the combination of diverse sets of impressions. These are often predominantly visual, as in *Formica fusca* and *F. rufibarbis*; they may be mainly olfactory, as in *Lasius flavus* and *L. fuliginosus*; in the very blind *Aphœnogaster barbara* they are mainly muscular.

The homing of bees and digger-wasps is even more striking than that of ants—so striking that Fabre felt compelled to postulate a capacity more subtle than ordinary memory, 'une sorte d'intuition des lieux'. He caught ten specimens of Cerceris, marked them, put them in a box, took them three kilometres away, and liberated them next morning. Of the ten, five returned to the home. Some specimens of Chalicodoma were taken over hill and dale to a distance of four kilometres, and twenty per cent. returned. Bethe liberated some bees in the middle of Strasburg and others at the same distance from the hive, but in the country; those from the streets were home (in the suburbs) before those from the country. Professor Yung, of Geneva, made a very interesting experiment. He took twenty bees from a hive near the lake, put them in a box, and took them six kilometres into the country, where they were liberated. Seventeen returned, some in an hour. Next day the seventeen were put back in the box and

taken on a boat to a distance of three kilometres on the lake. When liberated, they flew off in all directions, but none returned. This suggests that the bees build up a knowledge of the country round about them.

Bouvier concealed the entrance to the nest of a Bembex with a stone. This appeared to disturb the insect a little, but it lighted on the stone. When the stone was shifted, during the insect's absence, for about eight inches, the creature returned to the stone. It appeared to have fixed the stone in its memory. Further experiments go to show that bees and similar insects serve an apprenticeship, that they have a remarkable topographical memory, and that they begin by, so to speak, feeling their way from finger-post to finger-post. The Peckhams speak of the 'systematic study of the surroundings,' and others have described the trial flight of bees when they first leave the hive. Buttel-Reepen has shown that bees removed from the hive before they have had this 'orientation flight' do not return, and that if the hive be taken some miles off, a new apprenticeship has to be served.

There are other data, however, that go to support Fabre's assumption of an 'intuition des lieux'. Thus Gaston Bonnier observed that bees returned straight to the hive—making a bee-line, in fact—from a distance of as much as three kilometres. When they were carried afield in a box and then liberated, they made for the hive, which was quite invisible behind a wood. When their eyes were obscured with blackened collodion, they still found their way, which shows that vision is not necessary. The removal of the antennæ, which bear the so-called olfactory organs, did not prevent their return. These facts support the view that bees have a 'sense of direc-

tion', more or less comparable to that of carrier pigeons, and located in the cerebral ganglia.

The Peckhams made some fine experiments on 'homing' in social wasps. For instance, they captured a number of wasps leaving the nest in the morning, and, having stopped up the nest, took them to some distance off. The first lot was liberated a furlong out on a lake; the second in a barn with a window at each end—one towards, the other away from the nest; the third, three hundred yards away in the country. From fifty to seventy per cent. returned to the nest. It seemed to the observers that the wasps rose high in the air and flew about in circles until they saw something they remembered.

Some careful observations have been made on the 'homing' habit in limpets. In many cases, it has been shown that particular limpets have particular sites on the rock, and that they return to these after they have been on a short excursion. They appear to have a topographical memory, which fixes impressions not only of the particular site but of its surroundings. The reason why it matters that the limpet should 'go home', is that the margin of their shell grows so as to fit the little inequalities on the surface of the rock, and a small amount of water is thus retained during the period when they are left dry by the retreating tide. Lloyd Morgan found that of twenty-one limpets moved for eighteen inches, eighteen found their way back; of thirty-six moved for twenty-four inches, only five got home again.

'**Masking**'.—Various crabs, such as the common *Hyas araneus*, fasten seaweed on to their carapace, and thus cover themselves with effective disguise. When they put on an inconveniently large piece, they take it off again

and trim it. Some crabs use the tests of sea-squirts or pieces of sponge and zoophyte. In a number of higher crustaceans (crabs, lobsters, etc.), a salivated cement of sand is plastered over the carapace, making it very like the substratum. In species of the somewhat primitive type known as *Dorippe*, the posterior limbs are turned upwards and they hold the disguise—*which may be almost anything*, even a piece of glass—in position over the back. Most remarkable are the cases where crabs take seaweed of the colour that suits their usual background.

The process of masking in one of the spider-crabs (*Maja*) has been very carefully studied by Minkiewiez. The crab seizes a piece of seaweed in its forceps, puts it into its mouth and cuts off a piece, and then fixes this by means of its forceps on the back or on the walking legs. It moves the forceps backwards and forwards till the alga fixes on some of the recurved and barbed hooks borne on the carapace or legs. The same is done with sponge, hydroid and compound Ascidian, and Minkiewiez got his crabs to dress themselves up in pieces of silk paper. Professor Fol once made a similar experiment, giving the crab pieces of hay and white paper and depriving them of seaweeds. Unsatisfactory as the dress material was, it was duly utilized.

Minkiewiez made the interesting experiment of placing two or three thoroughly cleaned crabs in an aquarium and giving them pieces of silk paper of two colours—one the same as the environment and the other different, with the result that the crabs chose the pieces with the same colour as the surroundings. 'If the walls are white, they will be covered with white only; they will take neither green, nor yellow, nor black; if the walls are green, they

will be clothed in green'. In an aquarium divided into two with different colours (red and green), he placed crabs which had in a preparatory aquarium clothed themselves with red and green. The red crabs went towards the red end, the green crabs towards the green end. In an aquarium divided into three equal parts, the middle one white, the other two black, the white crabs went to the white part and remained there. In a control experiment in another aquarium, with black in the middle and white on both sides, the black crabs went for the black.

That the facts are suggestive of active masking and of deliberate choice must be granted, but Minkiewiez pointed out the danger of hurrying to a generous conclusion. He refers to Fol's observation that crabs could be got to put on a dress of white paper, which made them more, not less, conspicuous. He points out that clothed crabs transferred to an aquarium of a very discordant colour make no attempt to remove their old costume, though they hang on new papers beside the old ones. Furthermore, he found that crabs put into a black aquarium never took black paper if they could find any other colour. 'They cover themselves with green, red, or white, making a bright patch on the black floor of the aquarium, instead of concealing themselves'. The apparent contradiction between these exceptional facts and those which suggest deliberate self-disguise is very striking, and it led Minkiewiez to inquire carefully into its significance.

He found that blinded crabs disguised themselves at once, though without any reference to the colour of the surroundings. Whenever their claws touch suitable things the routine of reflex movements begins, their mouth-appendages are next touched, and then the dorsal hooks.

The brain is not required at all, which corroborates the observation of Bethe, that a crab in which the connexion between the brain and the ventral nerve cord has been cut, can walk and select its food and take its meals, and defend itself very much as usual. So, after the complete severance of the brain, one of Minkiewiez's spider-crabs was often seen to disguise itself, executing the whole series of movements in the proper order.

The power of discriminating between different rays of light is well seen in many animals. Minkiewiez has shown that the newly-hatched larvæ (Zoææ) of the spider-crab (*Maja squinado*) are strongly attracted to the light, and under a spectrum make for the rays of the shortest wave-length—the violet and blue. The red Nemertean worm, *Lineus ruber*, is negative with respect to diffused light, but when it is illumined by coloured light it makes for red and yellow rays and is repelled by the blue and green. In diffused light in an aquarium with a floor of two colours (say red and violet), it comes to rest on the red and avoids the violet. If the colour be other than red and violet, it always seeks out the background nearest red.

Hermit-crabs seem to be very suitable animals for experimentation, as they do not get excited and can be shifted about and placed here and there in an aquarium while within the shelter of their shell. They show a strong preference for a white background, and next to that for a green one. Apart from green, the attractive value of a colour corresponds to its position in the solar spectrum. In an aquarium with a floor half green, and half any other colour but white, the hermit crabs make for the green side whenever they get their eyes out of their sheltering shell, and Minkiewiez found that during the day they never

crossed the boundary line! The same applies to an aquarium half white, half black. The order of their preferences is thus :—

—Black → red → yellow → blue → violet → green → white +

The next result reached by Minkiewiez was very remarkable, that a change in the nature of the medium brings about a reversion of the attractions to the various rays. When distilled water was added to the sea water (25–80 cubic centimetres to 100 cubic centimetres), the Nemertean worm, *Lineus ruber*, turned towards the most refrangible rays of the spectrum as decidedly as it had previously avoided them! The change in the medium disturbed the physiological condition of the animal, but on the fourth day the original attractions manifested themselves again. When a worm which had got accustomed to the diluted water and showed its normal preference for red was put back again, after two or three weeks, into ordinary sea water, it was again disturbed, and made for the violet.

Hermit-crabs left in a basin without change of water become gradually intoxicated with their own waste products, and all their preferences are inverted. The scale of values remains in the same sequence, but the direction of movement has changed to the opposite, as in the following line :—

+ Black ← red ← yellow ← blue ← violet ← green ← white —

Professors Keeble and Gamble have shown that young prawns (*Hippolyte varians*), almost colourless to start with, rapidly assume the coloration of the seaweed on which they are placed. What is more, the adults that have put on some definite colour, are able to change this and assume a new one in harmony with a new environment. Minkiewiez got similar results : any colour can be changed

into any other, though some prawns are more susceptible than others. ' Once changed, the colour of the *Hippolyte*, even in the most obstinate, becomes plastic, and can be changed with astonishing rapidity, sometimes in ten minutes '.

According to Minkiewiez, what it seems to come to is this. In a green environment, the spider-crab becomes positively susceptible to green, and negative in relation to other colours. It will disguise itself in such green as it can find growing on the green surfaces. It does not choose its disguise. When it is transferred to an aquarium half red and half green, it goes to the green half, not because its disguise is green, but because it is itself attracted by green. It does not choose its environment. In a dark aquarium the crab may make itself conspicuous by putting on pieces of light-coloured paper instead of black paper, for any colour is more attractive than black, which has no influence at all.

The behaviour of the spider-crab in its self-concealment is composed of two parts. In the first place, it is drawn or driven towards certain coloured surfaces, according to the sum of the given conditions. Once there, and in touch with material—usually seaweed—it begins, in the second place, to cover itself, one set of tactile impressions provoking certain movements of the claws, which lead to tactile impressions of the mouth parts and further movements—and so on, until the whole routine is accomplished. We have given this case in some detail because it illustrates the work of the modern school, who rightly believe in pushing physiological interpretations as far as they will go before invoking an ' efficient consciousness ' or the like.

In Summary.—As regards the theory of instinct, there

are three main views: (*a*) Instinctive actions are regarded by some as concatenated reflexes, as non-cognitive hereditary dispositions to follow a certain routine when the trigger is pulled. (*b*) Instinctive actions are regarded by some as quite inseparable from intelligence. (*c*) Instinct and intelligence are regarded by Bergson and others as two radically different, though complementary, kinds of knowing, which have evolved along divergent lines. It is too soon to come to a decision in regard to these rival theories. The fact remains that there is a big area of animal behaviour of a peculiarly fascinating type which is conveniently called instinctive.

Intelligent Behaviour

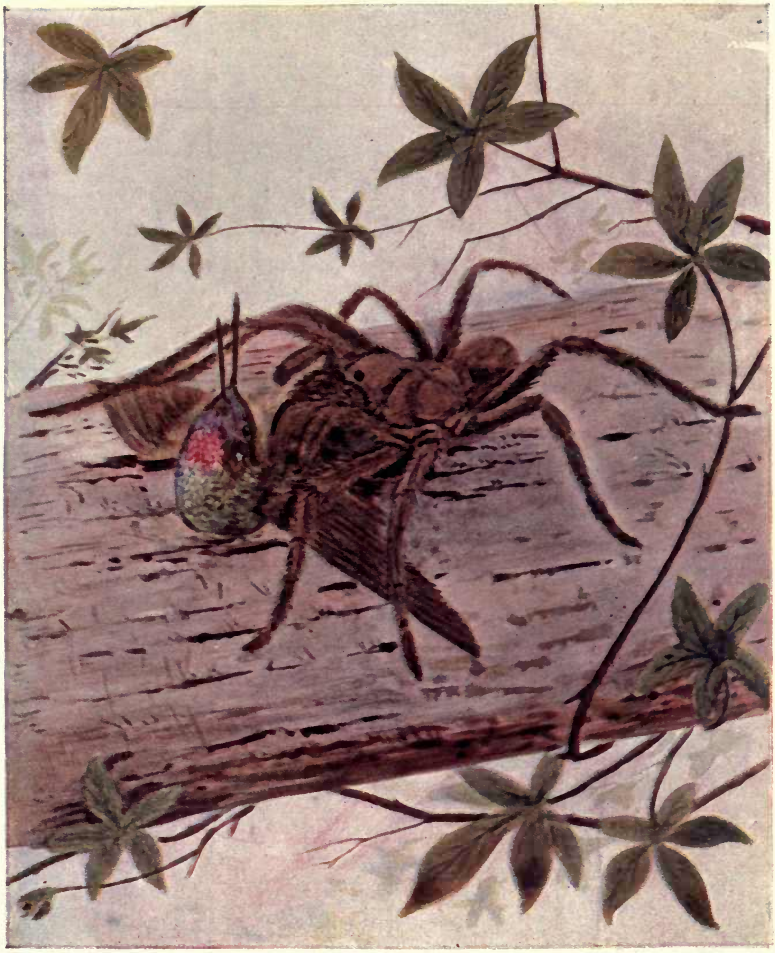
When we pass from the Invertebrates to the Vertebrates, we find ourselves in a new atmosphere. Instinct begins to count for less and intelligence for more. There are, indeed, many illustrations of intelligence among Invertebrates and of instinct among Vertebrates, but on the whole the big-brained type, which reaches its climax in Birds and Mammals, is one which is relatively poor in ready-made predispositions to certain lines of behaviour and relatively rich in its power of learning by experience. As Sir Ray Lankester has said, the big brain type is eminently educable.

After naturalists condescended to credit animals with intelligence analogous to their own, and ceased to bundle all animal behaviour together and label it 'instinctive', there was a generous reaction. It was the fashion to see a Brer Rabbit everywhere, and to read the man into the beast without let or hindrance. All sorts of delightful

anecdotes of animal sagacity were collected with more zeal than discretion.

We may associate with the name of Romanes in particular the beginning of a more critical period. Though he was not always sufficiently stern himself, he did important work in sifting the data, and in trying to separate out precise observation from the more or less unconscious inferences with which the recorder so often interpenetrates it. He drew the useful distinction between perceptual inference (intelligence), where a conclusion is drawn from concrete representations, and conceptual inference (reason), where the syllogism involves general concepts; and showed that there was no evidence compelling us to credit animals with more than the former. Considerable progress has also rewarded the work of the experimental school, who have studied the process of 'learning', of forming associations, of profiting by experience, of experimenting in novel situations, and so on.

Association.—It was a great step in evolution when animals began to associate sensations together. We mean by a sensation, physiologically, an impression made on the nervous system by external stimulus, and psychologically, an awareness (to some degree) of the external stimulus. Let us refer briefly to some of the experimental work which has been done in the study of the association of sensations. There is, for instance, the work of Pavlov and his school on the establishment of associations in the dog. It is well known that a dog's mouth may water when it sees food; there is a reflex stimulation of the salivary glands, not by direct contact with food, but circuitously by a visual impression. When the food is put in the dog's mouth, the salivation *must* follow; when the stimulation is cir-



cuitous the result is inconstant. Pavlov showed that if a whistle is always sounded when a dog gets something to eat, then by and by the sound of the whistle will make the dog salivate. An association between the sound and the gustatory excitation has been established.

The stimulus that 'suggests' the salivation may be almost anything if the dog has the association established—it may be, besides sight and sound, an odour, a movement, a change of temperature or illumination, a scratching of the skin, and so on. The method is useful in definitely proving the animal's sensitiveness to various stimuli—some of them well known to all who know dogs, and others a little surprising—but its chief value is in showing the establishment of cerebral associations, and in discovering their laws. The experiments leave in the mind a vivid impression of the remarkable plasticity of the dog's brain in forming associations. Thus, Orbeli succeeded in establishing a reflex between the salivation and the shape of the letter T (as distinguished from other shapes) thrown on a screen.

Bohn gives some other instructive illustrations. Many fishes show no sign of hearing sounds, and yet they sometimes hear them. For Meyer taught some fishes in a couple of months that whenever a certain sound was made they would find some food in a dark chamber in their aquarium. They acquired an *interest* in the sound and they came gradually to associate it with their memory of food.

There is a special interest in experiments with fishes, since their brain, especially in bony fishes, or Teleosts, has stopped at a low level. Some observers, like Edinger, deny them even memory. M. Oxner has recently made some instructive observations at the Oceanographical Museum

at Monaco with a fish called *Coris julis*, whose intelligence is at an interesting incipient stage. To begin with, he showed that when he disguised the hook very cleverly, he could catch the same fish as often as he pleased. But this only proved that the disguising of the hook was practically perfect, and that the fish was appetized. If there was no hint of the hook, there was nothing which an unreflecting creature could learn. A certain sensory impression raised a recollection of a pleasant experience, and action followed almost like a reflex.

Oxner's experiments with the sea-perch (*Serranus scriba*) are very instructive. In an aquarium he hung a red and a green cylinder by silk threads of a similar colour, and put food in the red one only. For the first two days the wary fish did not approach the cylinders at all. On the third day, after fifteen minutes' 'deliberation', it entered the cylinder and ate the food; on the fourth day it did this after five minutes; on the fifth day after half a minute; from the sixth to the tenth day it rushed in at once. On the eleventh day it entered a fresh red cylinder that had no food in it, and waited there for three minutes. So that one may reasonably conclude that an association had been established between the red colour and the food.

On each of the succeeding six days the fish rushed into the empty red cylinder, and when Oxner dropped in some food, a little was taken. On the eighteenth, nineteenth and twentieth days, the fish was unappetized and would not eat the food. But the interesting fact was, that even in the absence of appetite, the fish seemed unable to resist rushing into the red cylinder. The association worked almost like a reflex. It may be noted that there is no particular attraction in the red colour, for the same general

results were obtained when the food was put in a cylinder of another colour.

Bouvier was able to prove that wasps of the genus *Bembex* associated a certain stone, for instance, with the way to their burrow. It has been shown that the American crawfish, the crab, and the hermit-crab can be *taught* to take the more advantageous or the easier of two alternative paths. Anna Drzewina gave hermit-crabs which had been deprived of their shells a number of top-shells (*Trochus*) with the openings closed. The hermit-crabs spent futile days and nights trying to use the closed shells, but after six to eight days gave it up. Even when a shell with a paper lid was given them, they would not so much as try. They associated the form of the shell with failure. But when other closed shells of a different shape were given to them, they began eagerly again their futile attempts to win a way in.

Trial and Error.—In illustration of another experimental method, we may refer to Professor Thorndike's investigation of the learning powers of cats and dogs. He contrived cages with doors which could be opened by the manipulation of more or less intricate combinations of bolts and levers. Hungry cats and dogs were shut in and were tempted, by food placed just outside, to solve the problem of their prison-doors. In similar circumstances, we should probably do a little thinking, make one trial, and be free. But this was not what the cats and dogs did. They got out by the 'trial and error' method; that is to say, they made one experiment after another until they hit upon the fit and proper way of working the mechanism.

The experiment was repeated over and over again, and the curves recording the times taken to escape showed a

gradual descent. If the animals had ideas on the subject, they did not seem to use them. They learned by 'trial and error,' as we often do ourselves. But Professor Thorndike made an important step in suggesting that the pleasure of the meal that rewarded escape served to 'stamp in' the immediately antecedent association between the picture of the interior of the cage and the successful impulse that led to the succession of muscular movements effecting release. This is Professor Thorndike's 'sense-impulse' theory of learning.

When Thorndike's cats were shut up in boxes which could be easily opened in a particular way, they seemed to get out by accident. On subsequent occasions they did not take quite so long, and they gradually learned the trick. Dogs were quicker, and monkeys quicker still. In most cases the method seems to be the same—a chance discovery, and subsequently a gradual elimination of the ineffective attempts. But there appear to be some cases where it looks as if the animal had an intuition of the line of effective trial, as if it 'had a notion' of the best thing to do.

Experiments, especially in getting out of labyrinths, have been made with rats and guinea-pigs, chickens and sparrows, and some other creatures. The story is in most cases essentially the same. The animals learn more or less quickly to profit by their mistakes and to conquer the difficulties of the situation. In some cases (Watson's white rats) the learning appears to depend in great part on a muscular memory of the effective sequence of movements, for the elimination of sight, hearing and smell and a good deal of tactility did not seem to make much difference to the education in the maze.

Of great interest are the experiments made by Yerkes on ' dancing mice '. These fascinating creatures represent a peculiar variety, of unknown origin, which has been the subject of artificial selection. They are characterized by the inability to move far in a straight line without whirling or circling about with extreme rapidity. They are quite deaf, except sometimes during the third week of life. Their power of discriminating differences in brightness is acute, but their colour-vision, in the strict sense, is poor. They are quick to perceive movements, but make little of form. They have considerable powers of learning and can remember an acquired habit for 2–8 weeks after disuse. What has been forgotten is more quickly re-learned.

Dr. Yerkes arranged in their cage two passages, with doors which bore movable cards differing in colour or in surface. One passage led to food, the other to a slight electric shock. The food was sometimes to the right and sometimes to the left, but the door which led to it was marked with the same kind of card. When there were many changes the mice hesitated a good deal, going from one to another and touching the cards.

This point is of great interest, and must be emphasized. When the mouse found the right-hand door to be the path to food and freedom several times in succession, it tried the plan of keeping to that door. When it found that the cards were being alternated, it learned also to alternate. When it found that this did not work—when the changes were irregular—then it brought all its powers of discrimination to bear on the problem. The learning how to ' choose ' aright was quickest when the difference in the illumination of the two cards was most marked (colour *in itself* does not seem to count), and it was also noteworthy that when

fine discrimination was necessary, a strong electrical stimulation—the punishment of error—seemed to hinder, not to help, progress.

The case of the dancing mouse, so carefully studied by Dr. Yerkes, seems peculiarly interesting because of what one may call its nonchalance and inattentiveness.

'Most Mammals which have been experimentally studied have proved their eagerness and ability to learn the shortest, quickest and simplest route to the food without the additional spur of punishment for wandering. With the dancer it is different. It is content to be moving—whether the movement carries it directly to the food-box is of secondary importance. On its way to the food-box, no matter whether the box be slightly or strikingly different from its companion box, the dancer may go by way of the wrong box, may take a few turns, cut some figure eights, or even spin like a top for a few seconds almost within vibrissa-reach of the food-box, and all this though it be very hungry'.

But in spite of this lack of concentration, it learns to discriminate successfully.

It is difficult to know how much imitation counts for in animal behaviour. A monkey which has learned to work a piece of mechanism is sometimes able to teach others to imitate all the required movements, but often it meets with the variety of futile imitations that other teachers are familiar with. In one case, the simple trick of reaching a fruit with a stick was learned by one, yet never imitated by his companions. It is probable that in the natural life of the creature, and in the play period, imitation counts for much more than experiment has as yet indicated.

It is not even certain that a cat can catch a mouse without having been shown the way!

In regard to instinctive, as well as intelligent behaviour, it is probable that the influence of others counts for much —probably for more than is generally allowed. Taken singly, the ant, the bee or the termite has not a great deal to say for itself; but 'the co-operative work of the hive or nest is amongst the greatest wonders of nature'. 'This', says Professor Carveth Read, 'perhaps may be best explained by the incessant trying of all the operative ants, or bees, or termites, at their several tasks, in which individuals often fail, but have their work made good by the trying of others'. As Turner points out in his study of 'homing' in ants, the appearance of concerted division of labour may be deceptive, they supplement one another because all are trying. Thus, flurried ants carrying pupæ may hide these under a stone, and others who know the way may rescue the pupæ if they discover them.

As every one knows, a piece of behaviour which was 'thought out' to begin with, or required intelligent control at every turn, may be repeated so often that the brain is modified by its performance, and the need for attention and control ceases. In a word, it becomes *habitual*. 'A habit is a more or less definite mode of procedure or kind of behaviour which has been acquired by the individual and has become, so to speak, stereotyped through repetition'.

Instinct and Intelligence

When a newly-hatched coot or blackheaded gull is tumbled into water, it swims well—*instinctively*; when the hens come running when the hen-wife calls 'Tuck-Tuck',

they are putting two and two together in a simple way. When a dog turns round and round and smooths the herbage of the hearthrug into a bed for the night, it is obeying an ancient instinct; when it tries various ways of getting a stick with a crooked handle through a fence of close-set uprights, it is using its intelligence. When a horse shies at an unexplained rustling in the hedgerow, it does so instinctively; when it takes the market-cart safely home with the driver asleep, it does so intelligently. When inexperienced bees deal successfully with flowers, the performance is instinctive; when they set up house in a tree or mend a broken comb in an economical and effective way, intelligence is probably at work. When a bird utters its call-note before it is hatched, that is instinctive; when a parrot tells its mistress that it is dinner-time, that is more or less intelligent.

In these instances we have contrasted, in a simple way, instinctive and intelligent behaviour. It seems clear that whether the difference between them be of degree or of kind, there is a difference of sufficient importance to warrant the use of two different words. But it seems necessary to admit that it is not easy to discover either kind of behaviour in a perfectly pure form. Instinctive behaviour has often a spice of intelligence along with it, or is modified by intelligent 'learning'. Intelligent behaviour often utilizes instinctive dispositions as a basis.

That the distinctive call-note of a bird is *sometimes* instinctive is satisfactorily proved by cases where the characteristic sound is uttered before the young bird is hatched. Mr. Hudson cites the case of a young *Rhynchotus rufescens*, isolated when it was getting out of the egg-shell and reared beyond reach of education, which

was nevertheless accustomed, long before it was full-grown, to retire to a dark corner of the room and give forth its characteristic evening song. Young coots hatched in an incubator utter the same note as their fellows in natural conditions.

But this cannot be the whole story, for there is no reason to doubt the experiments made by the Hon. Daines Barrington, one of Gilbert White's correspondents. He reared linnets under skylarks, woodlarks, and titlarks, and found that they learned the song of their foster-parent in each case. This points to the conclusion that imitation counts for a great deal. It is likely that many young birds learn their song from their parents. Mr. Hudson reports that in the case of the oven-bird the parents sing a sort of duet together, which the young birds, when only partially fledged, practise inside the nest in the intervals when the parents are absent. Mr. G. W. Bulman, a careful observer, gives a circumstantial account of the yellow-hammer's singing lessons. The whole subject requires more attention and, above all, some careful experimenting.

The intrusion of intelligence upon an instinctive routine is probably seen when a bee that is unable to get at the nectar of a flower in the ordinary legitimate manner, proceeds to cut a hole through the base of the tube. Many years ago Hermann Müller pointed out that *Bombus terrestris*, which has a shorter proboscis than some other species of the genus, often tries in vain to suck the flowers of the oxlip (*Primula elatior*), and that it does not seek the short cut until it has convinced itself by experience that the other method will not work.

In many cases, however, bees which could suck the flower in the ordinary way, may also bite a hole through. Hermann

Müller found that this practice was especially common when flowers grow in masses and are very much visited. Gnawing the hole means losing time in the first instance, but it saves much time afterwards. The bees are able to discover more rapidly what blossoms are worth anything. The more minutely such facts are inquired into the more significant they become. Thus Professor Francis Darwin noted in regard to the wood-vetch (*Lathyrus sylvestris*) that the bee bites the hole just at the best place. The honey is secreted within a nectary enclosed by the united filaments of nine stamens; there are two 'nectar-holes' at the base; and the bees gnaw a hole exactly over the left nectar-hole, which is larger than the right.

'It is difficult to say how the bees have acquired this habit. Whether they have discovered the inequality in the size of the nectar-holes in sucking the flowers in the proper way, and have then utilized this knowledge in determining where to gnaw the hole; or whether they have found out the best situation by biting through the vexillum at various points, and have afterwards remembered its situation in visiting other flowers. But in either case they show a remarkable power of making use of what they have learned by experience'.

In other words, there is distinct intrusion of intelligence into the domain of instinct.

In further illustration of the subtle admixture of intelligence with instinct, one of Fritz Müller's observations may be cited. In a hive of Brazilian stingless bees (*Trigona mirim*), the workers had completed and filled forty-seven cells, eight on a nearly finished comb, thirty-seven on the following, and four around the first cell of a new comb.

'When the queen had laid eggs in all the cells of the two older combs, she went several times round their circumference (as she always does, in order to ascertain whether she has not forgotten any cell), and then prepared to retreat into the lower part of the breeding room. But as she had overlooked the four cells of the new comb, the workers ran impatiently from this part to the queen, pushing her, in an odd manner, with their heads, as they did also other workers they met with. In consequence, the queen began again to go around on the two older combs, but as she did not find any cell wanting an egg, she tried to descend; but everywhere she was pushed back by the workers. This contest lasted for a rather long while, till at last the queen escaped without having completed her work. Thus, the workers knew how to advise the queen that something was as yet to be done, but they knew not how to show her *where* it had to be done'.

What is called 'the plasticity of instinct' illustrates the modifying influence of intelligence. One of Romanes's examples may be cited. He took three orphaned ferrets and gave them to a young Brahma hen which was sitting on dummy eggs. She had never reared a brood of chickens, so she was quite unprejudiced. On the other hand, it is interesting to note that she had been nearly killed by an old ferret a few months before, so she should not have shown any partiality for that tribe. As a matter of fact, she took to them immediately, and she sat on them for rather more than a fortnight, nearly up to the time when their eyes were open. The ferrets were at first taken from the nest to be fed with milk, but as this procedure caused the foster-mother much uneasiness, they were afterwards fed in the nest—an arrangement with which the hen was perfectly satisfied. She seemed to be puzzled at the lethargy of her

'offspring', who could not, of course, follow her when she occasionally flew off the nest and summoned them. After one day she was quite aware of the meaning of the ferrets' hoarse cries, so different from a chick's piping note, and she would run in an agitated manner to any near place where Mr. Romanes hid them. There was no evidence, however, of a reciprocal understanding, for the ferrets showed no responsiveness to the hen's clucking.

During the whole fortnight the hen sat almost continuously.

'She used to comb out their hair with her bill, in the same way as hens in general comb out the feathers of their chickens. While engaged in this process, however, she used frequently to stop and look with one eye at the wriggling nest-full with an inquiring gaze expressive of astonishment. At other times, also, her family gave her good reason to be surprised; for she used often to fly off the nest suddenly with a loud scream—an action which was doubtless due to the unaccustomed sensation of being nipped by the young ferrets in their search for the teats'

This interesting case has many parallels, and the series of them afford astonishing illustrations of *the plasticity of instinct.*

Educated Animals

When we study horses, elephants, dogs, cats, monkeys, and other 'clever' Mammals, it seems necessary to admit that they have good memories, that they have a power of rapidly forming associations, that they profit by experience, that they can adapt old means to new ends, that they can 'put two and two together'. They must be granted the power of perceptual inference, and there are some facts con-

nected with the education of higher animals which suggest that we have swung to the extreme of crediting animals with too little mental capacity.

Every one knows that much can be achieved by the patient training and persuasion of big-brained higher animals, such as those which we have named, but no one yet knows how much. Elephants make very clever workers and the educability of army horses or of shepherds' dogs is astonishing. When the late Lord Avebury asked his dog Van if it wanted to go for a walk, it used to run to its box of printed cards and fetch the one with OUT on it. It would bring other cards, such as BONE or TEA, when it was invited to enjoy these luxuries. The same sort of associative power was even more developed in Dr. Romanes's chimpanzee, 'Sally', who would hand you three straws, or four straws, and so on, as you asked her. To save time, she used sometimes to double one of the straws and present the two ends between her fingers and thumb, making three straws do duty for four. And it was an interesting fact that when she was refused a reward in such cases, she used to straighten out the bent straw and make the number right by picking up another. This appreciation of numbers is very interesting, but it is mere child's play compared with the arithmetical powers that many hard-headed naturalists have recently felt compelled to recognize in the 'thinking horses' of Elberfeld.

The story of the so-called 'thinking horses' begins with 'Clever Hans', who was taught by Herr Von Osten to give, by stamping, the answers to a long and varied list of arithmetical questions. The case was carefully investigated in the Psychological Laboratory of the University of Berlin, and the general verdict was that the horse observed

its questioner very attentively and took note of ordinarily imperceptible and unconscious movements of the head and body which indicated when he should stop stamping. It was very clever of the horse to utilize the unconscious signals, but it was not arithmetic. Pfungst declared that 'Clever Hans' could not read figures or words, as was alleged, that he could not spell, or count, or perform arithmetical operations, and that even his memory was poor. It only remained to say that he was a very well-meaning and an uncommonly attentive horse. 'Clever Hans', rather shorn of his glory, passed into the hands of Herr Krall, a well-to-do merchant in Elberfeld, who took precautions (e.g. by using blinders) to keep him from receiving any visual signals during the experiments, and was still able to get correct answers. With increasing age, however, 'Hans' became tired of 'arithmetic', and would obstinately refuse to do any more of whatever it was that he had done. Convinced that the critics were missing part of the truth, Krall started afresh with two young Arab horses—Muhamed and Zarif—of two and two and a half years respectively, which previous experience with 'Hans' enabled him to train in a more effective way.

Krall accustomed his horses to the appearance of letters, figures, words, and the like, which were hung up in their 'schoolroom'; he taught them for one to two hours a day; he carefully avoided routine; he used 'blinders' to eliminate unconscious visual hints, and made an improved sounding-board for stamping the answers on. He taught his pupils to indicate units with the right foot, tens with the left, hundreds with the right, so that 126, which meant 126 stamps for Hans, involved only 9 for Muhamed and Zarif. 'Nothing', 'no', 'not' and 'none' were indicated by

one movement of the head from left to right. Gently and good-humouredly he taught them to associate a certain sound or sight with a certain number, a certain sound or sight with a certain object, or even operation. His education was run on association lines. Very gradually he got them, he thinks, to 'understand' addition, subtraction, multiplication and division. In the course of time they were able to deal with fractions and to extract square roots and cube roots. Dr. Hartmann, of Köln, got a friend to extract three cube roots and put the questions and answers in separate envelopes. In the stable he opened the first envelope and dictated, 'Cube root of 13,824'. In a few seconds came the answer, 24, which Hartmann confirmed by opening the relevant envelope. The cube root of 29,791 was stated to be 31. The cube root of 103,823 was given first as 57 and then, rightly, as 47.

Professor Buttell-Reepen got a friend to put a number of arithmetical questions in separate envelopes and the answers in others. Neither he nor Krall knew what they were. One was the square root of 3,364, and $\sqrt{}$ 3,364 was written on the board. Muhamed stamped 32 (wrong), 44 (wrong), then twice wrong, and then 58, which is right.

Professor H. von. Buttel-Reepen relates a very interesting experience. In September of last year he went one day, with Professor Ziegler, to Krall's stables half an hour earlier than had been arranged. In the yard they fell in with the Shetland Pony 'Hänschen', and resolved to make some experiments in the owner's absence. They got out the blackboard and the stamping-board, and without a word Professor Ziegler wrote down the sum $\frac{33}{11}$. Hänschen stood waiting before the stamping-board and at once

rapped out the correct answer. This is a very instructive instance. The pony had been taught at intervals for about six months; it had never been previously questioned in the yard, nor by strangers. A short distance off there was a groom brushing the yard, and another, Albert, was brushing Zarif, but they took no part in the proceedings; and before a second trial, Albert went into the stable. Another sum was written on the board, $\frac{12}{44}$, and the words were said, 'Now, Hänschen, add the two figures and you will get some carrots'. The right answer, which chanced to be the same as before, was at once rapped out. At this stage the owner and teacher appeared on the scene, but remained at a distance of five or six yards. The pony did two more sums, both wrong at the first trial, and then right. When the answer is wrong, and no reward or recognition is given, the pony begins to paw again, sometimes giving the right answer, sometimes persisting in the wrong one.

Just a little need be said about the spelling and reading lessons, which were not nearly so striking. A board was hung up, arranged on the plan indicated below:—

	1	2	3	4 etc.
10	e	n	r	s
20	a	h	l	t
30	i	d	g	w etc.
40				
etc.				

Each letter is denoted by two figures, units in the upper horizontal row and tens in the left vertical row. Thus *e* is represented by 11, which involved two stamps—one stamp with the right foot and one with the left; and *n* by 12, which involved two stamps with the right foot and one with the left. The horses insisted on spelling phonetically and in omitting the vowels; thus 'Pferd' was 'Ferd' and 'Essen' was 'S N' to them. It may be noted that Krall taught the alphabet and spelling on the old-fashioned lines. Pointing to 'k', he told the horses, 'this is ka'; pointing to 'p', 'this is pe'. It is hardly surprising that, even after six months' learning, the horses were very shaky about the spelling of a word like brod (bread), though they had strong practical reasons for making sure of a word with such pleasant associations.

Let us note, however, one of the spelling tests. Krall asked Muhamed if he wished a carrot, and got the usual emphatically affirmative nod. 'Well', said Krall, 'pay close attention; this gentleman's name is B-u-t-t-e-l (spelling it), spell that'. Muhamed began with an 'h', presumably for Herr, being a well-bred horse, and then wandered. Krall repeated with slow emphasis, Buttel, and the horse answered, 'bdul'. To the question, Where does the 'u' come in? Muhamed answered by stamping twice. 'Good', said Krall, 'then in the second place', and the horse answered, 'budl'.

The verdict of several competent observers, such as Professors H. Kraemer, P. Sarasin, H. E. Ziegler, Claparède, Buttel-Reepen, is to the effect that the horses do in some measure understand what they are being trained to do, that they do in some mysterious way calculate. Several general arguments may be used in support of

this view. (1) The horse is a very intelligent creature; it has a remarkably fine brain. Perhaps Krall's pupils are being led by him to cultivate fallow areas in their unusually rich cerebral estate. (2) The analogy of calculating boys is suggestive, for some of these have been very backward in other respects, unable to read or write, unaware of conventional methods of arithmetic, and so on. Professor von Buttel-Reepen cites the case of the Italian peasant-boy who extracted the cube-root of 3,796,416 in 30 seconds, and many instances are well known. (3) There may be some useful hint in the observation which several visitors have made, that the answers which are stamped out quickly and energetically are usually right. (4) Numerous mistakes are made, especially when the pupil is cross or distracted. It is of interest to notice, what Professor Plate and others have pointed out, that the number of mistakes increases with the difficulty of the sums. There was often a curious intelligibility in the mistakes, though an expert arithmetician has pointed out that the nature of the mistakes tells against the theory that real calculation is going on. That the horses are able to correct their mistakes is also of interest. Similarly, it is interesting that different experts who visited the horses got very unequal exhibitions of skill, or whatever it may be, and that the horses have refractory periods when they won't learn or won't show off. The fact that 'Clever Hans' has lost all interest in figures, finds its analogy in the case of Richard Whately, whose gifts as a calculating boy were quite replaced by others by the time he became Archbishop of Dublin.

What is to be said on the other side? Many have proclaimed their opinion that there must be some trickery some-

where, but this remains, on the whole, a vague innuendo. There is no evidence whatever that Herr Krall is other than a perfectly honourable and absolutely disinterested inquirer, anxious to get at the facts. Turning to concrete objections, we find that unbelieving critics have referred to the darkness of the stable; to the mesmeric influence of Krall; to the fact that the horses concentrate their attention on their master, the groom, and their carrots, and pay little heed to the problem on the board; to the continuous flow of remarks addressed to the horses by Krall in varied tones, from pianissimo to fortissimo; to the all too constant presence of the groom, Albert, who sometimes (according to Wigge) touches the horses suggestively! Each and all of these objections must be fully met by further investigation, but it is interesting to note that many of them have been already met by particular experiments, to some of which we have referred.

We have stated the two interpretations—each beset with difficulties. On the extreme sceptical view, the horses stamp out an answer which is somehow communicated to them by some practical joker who can compute rapidly, and who must be having the time of his life reading the literature on the subject. On this view, which is beset with great difficulties, the horses are showing remarkable sensitiveness to minute signals and extraordinary docility in their innocent complicity. It is plainly the task of further investigation to answer, one after another, all the objections which unfriendly critics have urged.

On the other view, which finds no evidence of trickery, the results seem indeed like the beginning of a new chapter in Animal Psychology. The horses have shown not only extraordinary powers of precise attention, concentration,

association, memory, but an unsuspected genius for dealing with numbers. Those who take this view need not, of course, accept Krall's generous conclusion that his horses think as men do, but they must give him credit as an educator who has been rewarded by the discovery of remarkable mental powers which at present elude analysis. In any case, it is for Comparative Psychology to continue the investigation on the strictest scientific lines and without prejudice.

A lady in Mannheim taught her Airedale terrier on Krall's methods. The dog learned to count and spell like Krall's horses. Professor H. E. Ziegler reports that he visited the dog, and drew on a piece of paper a mouse (Maus), a flower (Blume), and an elephant (Elefant). The dog spelled out 'Maus'; then Bliml, which is said to be the local dialect for Blume; and, finally, Kma Kral Brdo. The last was very puzzling, but it seems that the dog had seen several days before a postcard of Krall's young elephant, which is called Kama. Therefore, when shown Professor Ziegler's drawing, it spelled out Kma Kral. It may be that Brdo referred by some association of ideas to Krall's blind horse, Berto. As no one knew beforehand what was to be drawn, it is difficult to suggest that the dog was coached up, and we have Professor Ziegler's word for it that unconscious hints and trickery cannot be thought of for a moment.

CHAPTER V

THE WEB OF LIFE

(Intricacy of Inter-Relations)

'She is all things. She rewards herself and punishes herself; is her own joy and her own misery. . . .'

'Her children are numberless. To none is she altogether miserly; but she has her favourites, on whom she squanders much, and for whom she makes great sacrifices.'

—*Goethe's Aphorisms*, translated by Huxley.

The Balance of Nature—Linkages—The Living Earth—Mutual Dependence for the Continuance of Life—Ants and Seeds—Mussels and Minnows—Bees and Flowers—Other Illustrations—Inter-Relations of a Pitcher-plant—Ants and Plants—Epizoic Associations—Shelter Associations—Commensalism—Symbiosis—Parasitism—Domestic Complications—The Cuckoo's Habit—Animal Societies—The Ant Hill—The Bee Hive—The Termitary—Other Illustrations—Domestication—Guests and Pets—Slave-making—Man and the Web of Life.

ONE of Darwin's master-ideas has during the last half-century passed into general intellectual currency—the idea of the web of life. Nothing is unimportant, nothing is isolated, nature is a vast system of inter-relations and linkages. Earthworms have made most of the fertile soil of the Earth; cats have to do with next year's clover-crop; eighty seeds may germinate from one clodlet on one bird's foot. These are Darwinian instances and we are

constantly discovering new ones to-day. Every move on Nature's chessboard has consequences which may have a very long-lasting influence on the game. We know that the housefly puts an appreciable drag on the wheel of civilization, that squirrels affect the harvest, that wagtails have to do with the success of sheep-farming, and that cats may play a not unimportant rôle in determining the welfare of India.

As a corollary to Darwin's central conception came Pasteur's—the idea of the controllability of life. Silkworm disease and Phylloxera among the vines are not dispensations of Providence to be submitted to, they are handicaps to be got rid of. Olive pests in Italy and Vole plagues in Thessaly do not arise without good reason, and it is within our powers to alter these reasons. Tollitur causa, ablatus effectus.

The Balance of Nature

This phrase may serve to indicate the broadest kind of inter-relation, where two sets of living creatures, having evolved together, are dependent on one another, and on the persistence of an approximate equilibrium between them. It is possible to construct a closed-off aquarium in which the plants and animals balance one another perfectly for a period varying with the degree of uniformity in external conditions, and the carefulness of adjustment between the diverse constituents of the population. The oxygen required by the animals is produced in sunlight by the green plants, and the carbonic acid gas produced by the animals is utilized by the plants. The closed-off microcosm usually comes to an end by an over-production

of minute plants or by the accumulation of poisonous waste-products.

Taking a less artificial instance, we recognize the dependence of vegetarian animals on the plants of the given area. When the lemmings of a Scandinavian valley or the voles further south multiply exceedingly in times of plenty, they tend to check their own increase by eating up every green thing. Then the lemmings go on the march and the voles spread from parish to parish.

There is a necessary proportion to be sustained between herbivorous animals and plants, between carnivorous animals and herbivores, and one of the reasons of the ceaseless struggle for existence is just the clashing of the requirements of different kinds of creatures. The struggle goes on in a more or less inconspicuous sort of way until some environmental cause, such as peculiar weather, brings about a marked disproportion on one side or the other, and then there is a crisis.

Attention has often been directed to the 'beneficent provision of Nature' that animals which are preyed upon are, on the whole, more prolific than those which prey upon them. Thus, small Rodents tend to be much more prolific than Carnivores. The primary reason for this is probably that less individuated types tend to be more prolific. In a relatively stupid stock the variants in the direction of increased reproductivity will tend to survive. Great reproductivity will become the survival-securing quality of the feeble-minded types.

Birds keep down insects and small mammals, and they also distribute seeds. It is plain that any sudden reduction in their numbers will bring about disharmony in the order of Nature. Those who make such calculations

tell us that in the absence of birds the earth would be quite uninhabitable in six years. Certain it is that, as things are at present, the vegetation of the earth depends on birds. The grass of the meadow would soon be gone if birds did not thin the grubs in the winter and the spring. The trees of the woods would not long remain if the birds did not clean off the injurious insects. The small rodents, such as mice, popularly called vermin, are in many places bad enough as it is, but the hawks and owls save us from plagues. No one can deny that bullfinches destroy fruit-buds, that wood-pigeons devour large quantities of grain, that sparrow-hawks destroy many useful birds, that sparrows introduced into the States have been a national curse, and so on ; but these are quite exceptional instances. Even if we adhere to a somewhat narrow anthropocentric position, the balance of beneficence in favour of all but a few birds is overwhelmingly great. And it is absurd to suppose that Man, like a spoiled child of the Universe, should have everything made smooth for him, and should have no taxes to pay for his continual interference with the established order of things.

Prof. Alfred Newton once drew a vivid picture of the desolation likely to be wrought by man's carelessness in disturbing the balance of Nature—alike by introduction and extermination.

'What if a future *Challenger* shall report of some island, now known to possess a rich and varied animal population, that its present fauna had disappeared, that its only mammals were feral pigs, goats, rats and rabbits—with an infusion of ferrets, introduced by a zealous "acclimatizer" to check the abundance of the rodents last named, but contenting themselves with the colonists' chickens, that sparrows

and starlings, brought from Europe, were its only land-birds, that the former had propagated to such an extent that the cultivation of cereals had ceased to pay—the prohibition of bird-keeping boys by the local schoolmaster contributing to the same effect—and that the latter (the starlings), having put an end to the indigenous insectivorous birds by consuming their food, had turned their attention to the settlers' orchards so that a crop of fruit was only to be looked for about once in five years —when the great periodical cyclones had reduced the numbers of the depredators, that the goats had destroyed one-half of the original flora, and the rabbits the rest, that the pigs devastated the potato-gardens and yam-grounds.'

The destruction of small bats seems to be entirely wanton and foolish, for they help birds in thinning the hosts of fecund insects. It has been recently stated by Dr. C. A. R. Campbell, of San Antonio, Texas, that there is an apparent relation between mosquitoes and bats, that the former increase as the latter decrease. He suggests the establishment of shelters for the bats so that they may increase and multiply.

Linkages.—At every turn the naturalist finds proof that Nature is a vast system of linkages, and that it is quite unscientific to think of any organism as trivial or detached. The arc of its life may not enter the human field, but it is sure to enter many others, and one or other of its intersections may at any moment acquire significance for Man. One would not be inclined at first sight to attach much practical importance to the sea-gooseberries or Ctenophores, pelagic animals of the greatest delicacy and beauty. They descend into quiet water when there is any sea on; they re-ascend when there has been a lasting calm. Their

importance lies in the fact that they destroy large numbers of floating fish eggs and young fry. Dr. A. G. Mayer writes :—

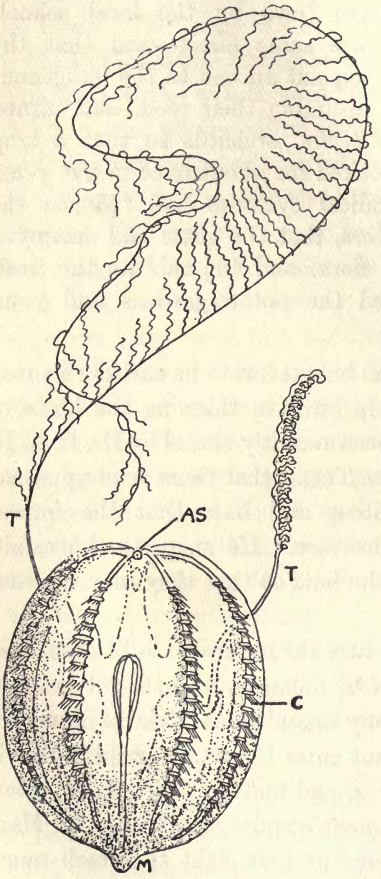


Fig. 45.—Ctenophore showing (T) retractile tentacles bearing adhesive cells; (M) position of the mouth; (C) line of ciliated combs; (AS) apical spot with a sensory organ. (*After* Mayer.)

'Tender as they are to the touch, passing jelly-like between the fingers of the hand that attempts to seize them, their food consists largely of young fishes, which they engulf in great numbers, seizing their prey by means of their peculiar adhesive cells. Thus, in the cold northern waters where ctenophores occur in vast swarms, they constitute a serious menace to the cod fisheries by devouring pelagic eggs and young fish.'

In almost all cases the ordinary stinging cells characteristic of jelly-fishes and other Coelenterates are absent from Ctenophores, but their place is taken by equally character-

istic adhesive cells which grapple with small animals passing by.

Another good instance of linkage, which is not obvious at first glance, is the connexion between fishes and malaria. But it is not a hard riddle to read. The parasite which causes malaria is disseminated by the mosquito, and the larval mosquitoes are devoured by many fishes. Captain R. B. Seymour Sewell and B. L. Chaudhuri have described eleven Indian fishes which are of proved value as mosquito destroyers. They conclude that 'fishes may be a very important agent in regulating and diminishing the degree of malarial infection in any given district'. It has also been suggested that the reason why the Barbadoes are remarkably free from malaria, is that the mosquito larvæ are devoured in large numbers by a small fish, popularly known as 'millions', which is very abundant in all the streams and pools.

The practical lesson to Man is the obvious one that he cannot be too careful lest he disturb the balance of things, by extermination on the one hand, or by transplantation on the other. We have elsewhere referred to important instances, such as the introduction of rabbits into Australia and of house-sparrows into the United States. We may refer again to the story of the rats of Jamaica. Rats brought by ships became a plague in Jamaica. To cope with them the mongoose (*Herpestes griseus*) was imported, and it made short work both of the Old World rats and the Jamaican cane-rats. But when these were gone, the appetite of the mongoose remained, and the poultry and various ground birds began to suffer. Useful insect-eating lizards were also eaten, and another cloud rose on the sky—there was a multiplication of injurious insects and ticks,

so that plants and animals began to be affected through an ever-widening circle.

Mr. Thomas Barbour has followed up the chain of consequences as regards reptiles :—

'The introduction of the mongoose has caused the almost complete extinction of many species which were once abundant, and has in some ways radically changed the facies of the fauna. In the back country, lizards are rarely met with, and it is only in the vicinities of villages and towns, where they are more or less protected, that one may obtain satisfactory series of many species. The true ground-inhabiting forms have, of course, suffered most, so that lizards of the genera *Ameiva*, *Mabuia* and *Celestus* are now scarce and difficult to obtain. Snakes have suffered perhaps more than lizards.'

An additional linkage in the case of the sparrow introduced into the United States has recently come to light, but it requires further investigation. The swarms of sparrows drive away other birds, but they also appear to exert an inimical influence on poultry in the wide sense (fowls, turkeys, ducks, geese, etc.). In the sparrow's intestine there are parasitic Protozoa, known as Coccidia, which occur in great abundance. The sparrow is accustomed to them, but when they pass to new hosts, such as poultry, they cause serious diseases, known as 'blackhead' or coccidiosis. The parasites also occur in the American 'robin' (*Merula migratoria*), the quail, and the Ruffed Grouse ; and perhaps there is a risk of making the sparrow a scapegoat.

The Living Earth.—As an instance of subtle interrelations, we may refer to some recent investigations at the Rothamsted laboratory. Drs. Russell and Hutchinson

found that when soils were heated or when they were dosed with certain volatile antiseptics, and afterwards brought into conditions favourable for plant growth, they showed a great increase in fertility. Further inquiry showed that the soil Bacteria are first reduced in numbers by the heating or sterilizing, and that after a while they increase enormously. To this increase is due a greater production of ammonia in the soil, and to this, of course, the greater fertility. But the puzzle is why the decrease after heating or sterilizing should be followed by a great increase.

The suggested solution of the puzzle is very interesting, and it is instructive even though it may require subsequent modification. There are many Protozoa in the soil, some of which feed on Bacteria and thus limit their increase. The Protozoa are more sensitive than the Bacteria to the heating or sterilizing. There is a killing off in both camps, but the Protozoa suffer most. In the period of recovery the surviving Bacteria multiply enormously in the relative absence of their enemies. This solution requires verification, and our knowledge of the soil Protozoa is still too scanty and vague. A great reward certainly awaits the investigator of the Protozoa of the soil. Mr. T. Goodey has listed about thirty already, but eighteen of these are ciliated Infusorians which exist in the soil in an encysted, not in an active state, and cannot therefore function as Bactericides.

Mutual Dependence for the Continuance of Life

Two organisms inhabiting the same area may become linked together in such a way that the continuance of the life of one of the two is dependent on the presence of the

other. Thus many flowers depend for their pollination on the visits of quite definite insects, who, in minding their own business of collecting pollen and nectar, unconsciously transfer the fertilizing dust from blossom to blossom. We shall return to this particular case after we have noted a few other illustrations.

Fruit-eating birds, such as thrushes, are responsible for the distribution of many seeds. Many water-birds carry minute animals from one watershed to another, and there is indeed quite a fauna and flora of birds' feet. Earthworms sometimes plant trees and the squirrel's forgotten stores may serve to start a coppice. The world is full of such linkages. We may refer to the rôle of ants as a less familiar illustration.

Ants and Seeds.—It has been known for a long time that ants carry to their nests the seeds of the cow-wheat (*Melampyrum*), and it has been suggested that in doing so they labour under a 'misapprehension', as one might say, confusing them with pupæ. There are some details which support this view, which may have something in it. Probably, however, the ants know better, and the theory does them injustice. For further research has shown that ants have a very marked predilection for certain seeds and fruits, and carry them about for great distances.

Experiment has shown that ants are particularly fond of seeds which have 'food-bodies' or 'oil-bodies' in their coats, such as violet, bluebell, mignonette, and fumitory. In many cases the ants carry the seeds to the nests, but eat only the external food-bodies, so that the thrown-out seeds may still germinate. Moreover, in many cases the seeds are lost by the ants on their journeyings. Prof. F. E.

Weiss took the seeds of the gorse, which have a bright orange, fleshy food-body, and placed them on ant-tracks. He found that they were rapidly picked up by the ants, while seeds of various other plants were left alone. The seeds of the broom, which have a food-body like that of the gorse, were treated in the same way. It seems legitimate, then, to conclude that ants assist in the distribution of gorse and broom.

Mussels and Minnows.—The freshwater Mussels (Unio and Anodon) are bound up in the bundle of life with fishes, such as minnow and stickleback. The mussel keeps its larvæ in a capacious cradle within the outer gill-plate, and does not allow them to escape until a minnow or the like comes into the immediate vicinity. When the crowd of free-swimming bivalve larvæ find themselves in the water near the fish they show manifest excitement and move towards it, snapping their valves, which bear minute attaching hooks. Fine anchoring threads of a glutinous character are also exuded, and attachment is effected to the minnow's skin. For a considerable time the larvæ remain fixed to the fish, pass through a kind of metamorphosis, and eventually fall off into the mud—perhaps far from the place where their parents lived. There are many interesting points here—the hereditary attraction of the mussel larvæ to the fish (in the laboratory they are excited by even a piece of fish), the special adaptations which secure attachment, the metamorphosis, the distribution; but what we wish to emphasize is the broad fact that two creatures as different as possible—the mussel and the minnow—have got linked up together. The minnow is quite passive in this linkage, but it is an extremely interesting fact that a continental fish, the bitterling (*Rhodeus amarus*), should spend part of

its early life as a semi-parasite inside the gill-cavity of the freshwater mussel.

Bees and Flowers.—The inter-relations between bees and flowers have formed the subject of many studies and of many controversies. For the matter is not so clear and simple as is sometimes represented. Bees visit the flowers for the pollen and the nectar. The cane-sugar of the nectar is transformed into glucose and is consumed as food by its collector, or is stored in cells. The pollen serves as food directly, or it is mixed with honey to form a nutritive paste or jelly for the young. In hive-bees there is often a good deal of method in the collecting; Aristotle noted rightly that they often keep to one kind of flower at a time. There is often division of labour among the workers, for some collect nectar and others collect pollen. The adaptations on the bees' part are many, but the most important are the suctorial mouth-parts and the pollen-collecting hairs on the legs.

The egg-cell of a flowering plant hidden away within the ovule within the ovary does not usually develop into an embryo unless it be fertilized by a male element (nucleus) within the pollen grain. The pollen grains are dusted on to the stigma of the pistil in various ways—usually by insects or by the wind or by shaking—and from a pollen grain a pollen-tube grows down in search of the egg-cell. It is a nucleus within the pollen-tube that effects the fertilization proper and sets development agoing. Unless this happens, the ovules or possible seeds do not become real seeds containing embryos.

Now it is well-known that although self-fertilization occurs (e.g. in peas), cross-fertilization is predominant. That is to say, fertilization is usually effected by pollen

from another plant, and sometimes that is the only possible mode. It was one of Darwin's great services that he showed by experiment the advantages of cross-fertilization as against self-fertilization where that is possible. The plants that grow from cross-fertilized seeds are more robust, tend to flower earlier, and have more numerous and better seeds. In Mexico the vanilla is cross-pollinated by bees; in other regions the stamen is rubbed against the pistil artificially; there is said to be no doubt as to the superiority of the Mexican vanilla. Darwin also pointed out the interesting fact that if there be placed on a stigma a pollen grain from the same flower and a pollen grain from another plant of the same species, the pollen-tube of the latter grows more rapidly and usually wins the race for the ovum. If the conclusion be accepted that cross-fertilization is the advantageous mode, then the importance of bees and other flower-visiting insects is plain, for it is they who unconsciously effect the pollination. On their visits to flowers various parts of their bodies are dusted with pollen from the stamens, and when they pass on to other flowers of the same species they mechanically and inevitably transfer the pollen to the stigmas.

If the bees are useful to the races of flowering plants which they visit, as experiment proves, and if the flowers are useful to the bees, as is evident, then we should on general grounds expect to find a variety of adaptations fitting the bees to make the most of the flowers and fitting the flowers to make the most of the bees. That is what is found, and it is very instructive to notice that there is, so to speak, a long inclined plane of adaptiveness, some bees being much fitter flower-visitors than others, and some flowers making much more of the bees than do others.

The climax of bee evolution is exhibited by the hive-bees (*Apis mellifica*), which we mention in the plural because there are a good many varieties which again differ in their degrees of fitness. The especial fitness of the hive-bee is to be found in the perfection of the arrangements for collecting and carrying the pollen and for sucking the nectar. It is interesting to find that apiarists have for years practised some measure of selection with the hive-bee, just as the breeder with his horses and cattle, paying special attention to such points as the length of the tongue (which they measure with a glossometer!)—the desire being to control its length.

The controversy really begins when we inquire into the adaptiveness of the flowers to their visitors, for there is one school of naturalists who insist in interpreting floral characters as the outcome of a selective process in which insects have played the leading rôle, while according to another the selective rôle of insects is of quite subsidiary importance.

The extreme position in regard to the rôle of insects was long since expressed by the late Lord Avebury, then Sir John Lubbock.

'Not only have the form and the colours, the bright tints, the sweet odours and the nectar been gradually developed by force of an unconscious selection exercised by the insects, but even the arrangement of the colours, the shape, the size and the position of the petals, the relative position of the stamens and pistil, are all determined by the visits of the insects, and in such a way as to assure the great object (fertilization) that these visits are intended to effect.'

The famous French botanist, Gaston Bonnier, has been foremost in maintaining that the plant secretes nectar for

its own use, and would secrete nectar were there no bees. The nectaries are manufactories where cane-sugar (due to the starch made in the leaves) is worked up and stored—usually for the fruits and seeds. The drops that are sweated out, as night falls, from the nectaries never contain more than a small part of the sugar of the nectaries; they correspond to water-drops elsewhere, except that they are more or less rich in sugar; if insects do not suck them up they are re-absorbed in due course. This appears to be a very effective objection up to a certain point. It shows that the primary significance of the nectaries is for the plant itself. We wish to point out, however, a rule in scientific method which has its application here, namely, that one must be careful not to mix up problems of *origin* with problems of subsequent *evolution*. Bonnier's evidence that the primary significance of nectaries is for the plant itself, is not inconsistent with the view that bees and other insects may have had something to do with the evolution of these organs, e.g. in determining their precise position. It remains a fact that bees tap them, and it is probable that these visits of bees have, in the course of ages, had some selective influence on the plants.

In regard to the fragrance of flowers the case is just a little different. It cannot be said that the fragrance as such is of direct use to the flowers. It may be a quite incidental property of chemical substances which are important in the metabolism of the plant. But in the same way it may be argued that the sweetness of nectar is not as sweetness of direct use to the plant. The sugar need not have been sweet, and the chemical substances referred to need not have been aromatic. As it appears to us, clearness comes when we separate the two problems—of origin

and of subsequent evolution. The answer to the question of the origin of substances of sweet odour is to be found in the physiological study of the plant. But the subsequent success of flowering plants with particular odours may have been due to the fact that these odours attracted useful insect visitors and repelled intruders. There is no doubt that bees are attracted by the fragrance of honey and of certain flowers. Bouvier quotes the pretty observation of Perez that bees frequenting the willow catkins in the early Spring are always to be seen coming from the side toward which the wind blows the fragrance.

Thirdly, there is the question in regard to colour, which is the most difficult of the three. For while it is certain that bees like sweetness, and that bees like certain odours, it does not seem so certain as was once supposed, that bees like particular colours. There are some difficulties. Bonnier put a row of painted blocks—red, green, white or yellow—on the turf near some hives and baited each with honey. They were visited impartially by the bees, but with a slight preference for green. It is said, however, that when bees are preoccupied with flower-visiting they do not pay much heed to other things. It must also be remembered that the flower is to the bee a complex of sensations appealing to sight and smell and taste; and that in trying to get at the truth by analysis one may land in fallacy.

Forel put coloured artificial flowers in a basket of dahlias and baited them with honey. The bees kept to the dahlia till an inquisitive or blundering individual discovered the treasure in the artificial flowers. These were then thoroughly explored, except the green ones. Even after the

honey had been removed the visits continued—perhaps because of pleasant memories.

Some interesting experiments made by J. Wery go to show that colour and form of the flowers count for much. He removed the corollas from a number of flowers and left others uninjured. The position of the flowers was changed from time to time. In the one experiment, in the month of June, the uninjured flowers were visited by 107 insects, of which 72 were bees; the flowers without corollas, but still conspicuous, were visited by 79 insects, of which 28 were bees. He also found that artificial flowers were freely visited and that a glass vessel with honey was left alone. In all these experiments there is the defect that they deal with bees who have already established associations. Crucial experiments should be made with inexperienced bees.

In regard to colour, our conclusion is as before. The origin of the coloured substances is a physiological secret of the plant, but in so far as the colour has formed an important part (how important remains to be proved) of the complex of attractions which draw the useful insect-visitors, in so far it will tend to persist and perhaps increase in the course of selection. But there can be little hesitation in accepting Claude Bernard's general conclusion :—

'The law of the physiological finality is in each individual being and not outside it; the living organism is made for itself; it has its own intrinsic laws. It works for itself and not for others.'

Spoiling an Adaptation.—It is well known that the common *Bombus terrestris* is very much given to biting a hole through the base of the flower of the red clover, and

is therefore of little or no use in pollination. The other species of humble-bees enter by the mouth of the flowers, and it is their visits that really count. Mr. Thomas Belt made the interesting observation that in the beginning of the season some individuals of *Bombus terrestris* visit the flowers of the scarlet-runner in a legitimate manner, but soon discover that there is a shorter way by biting a hole. They burgle unopened buds in the same way, and the hive-bee has learned to utilize the humble-bee's perforations. Large gaping flowers such as those of Foxglove and Nasturtium are pollinated by *Bombus terrestris*, but the narrower ones are cut through and despoiled without benefit.

The Case of the Fig.—Of all the mutual relationships that are involved in pollination, those concerned with the fig are perhaps the most remarkable. The whole story has not yet been cleared up, and it is too complex for full discussion here. Utilizing a luminous article by Prof. F. Cavers, we shall simply seek to explain the intricate part which certain minute wasps play in the fertilization. As is well known, the flowers of the fig are formed within a hollow, pear-shaped receptacle with a narrow mouth. Just below the mouth are the male flowers ; the rest of the cavity is lined by the female flowers ; all are very minute. Early in Spring a female wasp (usually *Blastophaga grossorum*) enters the cup of the early *inedible* inflorescences of the wild fig before the male flowers are open, and lays her eggs in the female flowers. These eggs hatch into wingless males who never escape and winged females who fly away after they have been fertilized by the males. As they creep out they get dusted with pollen from the male flowers which have meantime opened. They visit a later crop of

edible figs, and the female flowers, saved by long styles from having eggs laid in them, are pollinated and produce normal seeds. The female wasps go in and out till the swelling of the juicy inflorescence nearly closes the opening. They then migrate in autumn into small late *inedible* figs, where they lay eggs. These eggs hatch into wingless males and winged females, which remain inside the small figs through the winter. The females escape in Spring before the dry figs fall off, and then the story begins again. We must not pursue the matter further: it is complicated by the existence of two cultivated varieties of the wild fig—the inedible *caprificus* with male flowers only, and the ordinary edible *domestica* with female flowers only. Both are visited by the Blastophaga wasp.

Other Relations Between Plants and Animals

Many animals feed on plants; many animals have their home on or in plants (*see* Parasitism); many animals secure the pollination of flowers and the distribution of seeds; a few animals hide themselves with a disguise of plants (*see* Masking); a few animals have entered into an internal partnership with plants; but this list does not by any means suffice to cover the extraordinary diversity of interrelations. Let us refer to a few of the many other kinds of linkage.

Alga on Sloth's Hair.—A quaint association seems to have become established between a unicellular Alga, like the *Pleurococcus* which makes tree-stems green in wet weather, and the shaggy hairs of the South American sloth (*Bradypus*), which lives an altogether arboreal life. The sloth has almost exactly the same greyish-green colour as

Tillandsia usneoides, the so-called ' vegetable horse-hair ', which is common on trees, and it is almost certain that this colour-resemblance has protective value.

Ambrosia.—In the tunnels made by various beetles (e.g. species of Xyloterus and the like) in the bark and wood of trees there is a lining of Fungus, which produces special spherical ' ambrosia ' cells, serving as food for the insects. This association appears to be useful to both organisms: the insects are fond of the ' ambrosia ', and its growth makes up for the frequently poor nutritive quality of the wood; the fungi profit because the larvæ carry them in their borings into the sapwood, where they get the best food and have at the same time a good supply of air. The association has been carefully studied by Prof. Neger, who regards it as a genuine symbiosis. It is much commoner in warm and tropical zones, where the boring insects often do much harm both by their own operations and by introducing the fungi, most of which seem to be related to the Ascomycete genus Endomyces. The matter may become more complicated—wheels within wheels again—when weeds begin to grow in the fungus garden in the form of yeasts and Bacteria and the like which further infect the wood, but are not of any use to the beetles.

Neger found the same ' ambrosia-cells ' inside the galls made by certain mites (*Asphondylia*). The cavity of the gall is lined by a layer of fungus threads, among which are the special ' ambrosia cells ' which the developing mites eat. After the mites have departed, the spores of the fungus are produced on the outer surface of the gall. Here, then, there is a triple combination of flowering-plant, mite, and fungus.

Plants Turning the Tables.—Even the worm will

turn and even the plant may retaliate. Many plants are full of deadly poison; many are densely infiltrated with crystals from which even snails turn aside; many have thorns and spines which though primarily expressions of peculiarities of constitution are often secondarily protective; many have moats and railings which entrap or ward off unwelcome insect visitors; and so on through a long list.

More actively retaliatory are the carnivorous plants, like the butterwort (*Pinguicula*), which attracts insects to its glistening glandular leaf and there digests them, like the bladderworts (*Utricularia*) with their neat traps for water-fleas, like the sundews (*Drosera*) with their finger-like tentacles, like the pitcher-plants (*Nepenthes* and *Sarracenia*), catching very passively, and Venus's Fly-Trap (*Dionœa*), capturing very actively, and so forth. Here there is a definite turning of the tables.

A hint of the retaliatory power of the plant is familiar in the stinging nettle (*Urtica dioica*), with its hairs containing formic acid, but the capacity reaches its climax in a large member of the order Urticaceæ, the 'stinging-tree' (*Laportea*), species of which occur in Japan, Eastern India and Queensland. A light touch of a leaf produces a virulent effect lasting for days or even months. The pain is described by men who have been stung as maddening and agonizing, and the effect on horses and dogs is also very severe. The Australian species may attain a height of 10–15 feet and is said to emit a disagreeable odour.

Inter-Relations of a Pitcher Plant.—Let us take one case in more detail. In studying one of the insectivorous plants, the Spotted Trumpet-Leaf, *Sarracenia variolaris*, whose long tube forms a very effective trap, Prof. C. V.

Riley discovered that there were two common insect visitors, that came and went and were not destroyed. One of these is a flesh-fly (*Sarcophaga sarraceniæ*), which is attracted by the odour of putrescence and deposits its maggots (it is viviparous) in the rotting material, with remains of ants, flies, moths, beetles, katydids, crickets, and the like, at the bottom of the pitcher.

The whitish maggots riot in the putrid insect remains, but, of the dozen or so that there are to start with, ' usually but one matures, even when there appears macerated food enough for several '. A fratricidal warfare is waged which reduces the numbers in this remarkable way. When the survivor has attained its full larval size it bores through the leaf and burrows in the ground. After a few days' pupation it issues as a large two-winged fly. Two questions naturally present themselves, Why the adult escapes the fate of all but one of the other insects that enter or tumble into the tube ? and Why the maggot is not killed in the noxious fluid in which it revels ?

The fly is probably safe because it has strong, spreading legs with large adhesive surfaces and strong claws, which enable it to get a grip of the cellular tissue of the pitcher surface in spite of the slippery downward-projecting hairs. When it is disturbed within the pitcher it buzzes about violently and emerges in most cases successfully. It is more difficult to explain the survival of the maggots, except by simply pointing to other cases where dipterous larvæ live in what seem to be hazardous situations, e.g. inside the food-canal of a higher animal or inside decaying matter.

The other intruder, who successfully braves the dangers of the trap, is a little glossy moth, marked with grey-black

and straw-yellow. This Sarracenia moth (*Xanthoptera semicrocea*) walks with impunity on the treacherous inner surface of the pitcher and the female lays her eggs singly near the mouth. The young larva spins for itself a carpet of silk and draws the rim of the pitcher together with a web which shuts out all other insects. It works its way down the wall of the pitcher, devouring the cellular tissue, and dropping large quantities of undigested food into the cavity. It is a half-looper caterpillar, with beautiful cross bands of white and purple or lake red, and prominent rows of tubercles. 'It keeps up, in travelling, a constant, restless, waving motion of the head and thoracic joints, recalling paralysis agitans. The chrysalis is formed in a slight cocoon, usually just above or within the packed excrementitious material. There are two broods in the year'.

Here we have two good examples of strange habitat and strange mode of life. The flesh-fly is 'a mere intruder, the larva sponging on and sharing the food obtained by the plant'. The moth is an active enemy spoiling the Sarracenia trap.

Ants and Plants.—The associations between ants and plants show various degrees of intimacy. Ridley distinguishes three groups: (1) The ants may be sheltered within the leaves or flowers, within hollow stems or thorns, and so on, without deriving any food from the plant or conferring any benefit on it. (2) In the case of some epiphytic ferns and orchids, the ants that shelter about the base of the plant bring up considerable quantities of soil. (3) Much more intimate, however, are those cases where the ants live in hollow stems, branches, or spines, and while feeding on secretions exuded by glands of the plant, give this benefit in

FIG. 46.—Acacia Twig (Acacia sphærocephala), about two-thirds natural size. (*After* Schimper.) 1. The large hollow thorns which are tenanted by ants. 2. An entrance bored through a thorn. 3. Small inflorescence. 4. A compound leaf in resting position. The bodyguard of ants which live in the shelter of the acacia do it no harm. On the contrary they ward off the attacks of the formidable leaf-cutter ants.

return that they form a bodyguard, warding off the attacks of other insects.

An association that still requires a good deal of clearing up is that between ants and the labyrinthine stem-tubers of *Myrmecodia tuberosa*, a famous Javanese epiphyte. The tuber has many passages and caverns, which

are tenanted by ants (*Iridomyrmex myrmecodius*). Beccari thought that the ants were responsible for making the labyrinth, but Forbes and Treub proved that there could be typical labyrinths in the entire absence of ants. It seems certain, indeed, that the tuber is a water-absorbing and water-storing organ, very useful to a plant which lives quite off the ground. At the same time the association with ants is very general. Miehe points out that some of the walls of the maze are smooth and light brown, while others are warty and dark brown. A dark fungus grows on the rough surfaces, not on the smooth. The ants deposit their excrement on the rough surfaces; they use the smooth-walled chambers as nurseries. It is probable, Miehe thinks, that the excrement of the ants is utilized by the plants; and this, if the case, may be a very useful arrangement for an epiphyte living off the ground. The ants get a convenient shelter. They do not seem to eat anything that belongs to the plant, though what they eat is unknown. Nor do we know whether they can get along without their maze.

Epizoic Associations.—Many plants, such as Lichens and Orchids, grow upon other plants, and are known as epiphytic, and the term may be also applied to animals which are practically confined to certain plants, e.g. various Hydrozoa and Polyzoa on seaweeds, not in any real parasitism, but because the situation suits them well. Similarly, we have epizoic plants and animals. The green Alga on the Sloth's hair is epizoic. The seaweed on the limpet's back is epizoic. We do not know that there is any value in the last association, though with some slight change of conditions it might readily become invested with such value. In the same way there are many examples of

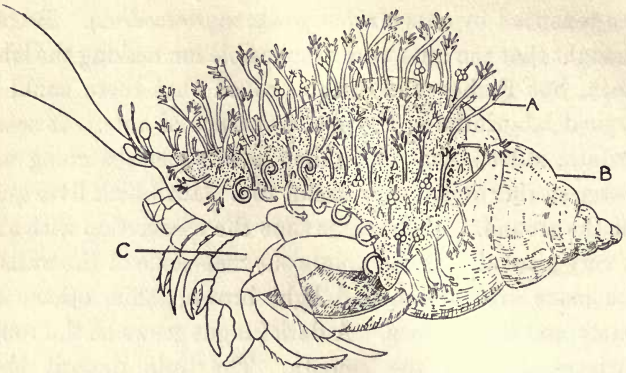


FIG. 47.—Epizoic growth of hydroid polyps—Hydractinia (A), on shell of whelk—Buccinum (B), which is tenanted by a hermit-crab. Forceps of hermit-crab (C). The hydroid colony shows division of labour; it includes nutritive, reproductive, and other types of individual.

epizoic animals: acorn-shells on bivalves and crabs, Serpulid worms on shells, Hydrozoa and Polyzoa on many kinds of marine animals, one sponge on another and so on. Weber refers to the fact that the muddy floor of the Banda Sea is covered for miles with a dense network of a large Foraminifer, *Rhizammina algæformis*, and that this serves as a suitable substratum for a large number of sedentary animals, which could not otherwise find a foothold in the soft mud.

Of many of these epizoic marine animals it must simply be said that they grow upon other marine animals just as they might grow on any other object. The young stages happened to land there and found the substratum suitable. This must be true of the acorn-shells (*Balanus*), false-oysters (*Anomia*), serpulid worms, Polyzoa, zoophytes, and the like often found on crabs, which do not seem to illustrate more than fortuitous epizoic association. But some

of the cases are difficult. Thus Dr. W. T. Calman describes a crab from Christmas Island which had a hydroid polyp, allied to *Stylactis*, attached like a tassel at the 'knee' of each of its legs. All but two of the polyps were symmetrically disposed and the rootwork (or hydrorhiza) followed the grooves on the carapace. Moreover, the type specimens of the species of crab (*Medœus haswelli*), although coming from another and distant locality, were found to bear similar or identical hydroids.

Prof. Alcock has described the curious association between a Hydroid (*Stylactis minoi*) and a small rock perch (*Minous inermis*); but even more remarkable is Prof. Willey's case of barnacles growing on a sea-snake. His figure, almost mediæval at first glance, shows a bunch of two kinds of barnacles (*Lepas anserifera* and *Conchoderma hunteri*) attached to the end of an Indian Ocean sea-snake (*Hydrus platurus*). The barnacles are not in any way parasitic, they are simply epizoic; the free-swimming young forms happened to fix themselves to the snake instead of to a drifting spar. But it is interesting to notice that their occurrence on snakes has been repeatedly recorded. To the snake, one would think, they must prove themselves a troublesome incubus, seriously impeding its movements.

Some of the epizoic associations certainly become dangerous to the bearer. Prof. Charles Chilton describes such a case in the crab *Paramithrax longipes*, which seems to be almost invariably accompanied by specimens of the acorn-shell *Balanus decorus*, growing on its carapace and sometimes becoming so large and numerous that they exceed in size the body of the crab itself. The association was probably quite unimportant in its initial stages, but gradually, as the cirripedes grew, they must have become inimical

to the crab's welfare. It is understood, of course, that as long as the crab is growing, it moults periodically and gets rid of its associates in casting its shell. It is after growth has stopped that the burden tends to become too heavy to be borne.

The sucking fish Echeneis illustrates the difficulty of classification. It fastens itself temporarily to other fishes, to turtles, and even Cetaceans, but uses them simply as a means of transport. It is no more a parasite than a man on horseback.

Shelter Associations.—No hard and fast lines can be drawn, but it seems useful to group together as 'shelter associations' a number of interesting cases in which one animal finds shelter in or about another, without itself conferring any benefit in return.

Fierasfer is one of the best examples of shelter-association. It goes in and out of sea-cucumbers, starfishes, and big bivalves, but it feeds independently like any other fish. The fact is that it belongs to a family (Ophidiidæ) of light-avoiding fishes, such as the sand-eel Ammodytes, and yet is very dependent on the freshness of the water. Thus it occurs in the shelter of animals in which there are active currents of water.

The entrance of Fierasfer into its sea-cucumber host has been described by Linton. Apparently by accident the fish touches the body of the sea-cucumber (in this case *Stichopus moebii*), with its snout; it at once feels its way backward to the posterior end without any pause, as if it was following a scent; vision does not seem to count for much. When it touches the cloacal opening it brings its slender tail sharply round with a rapid whip-like movement and thrusts the tip in. Up to this point the fish is excited;

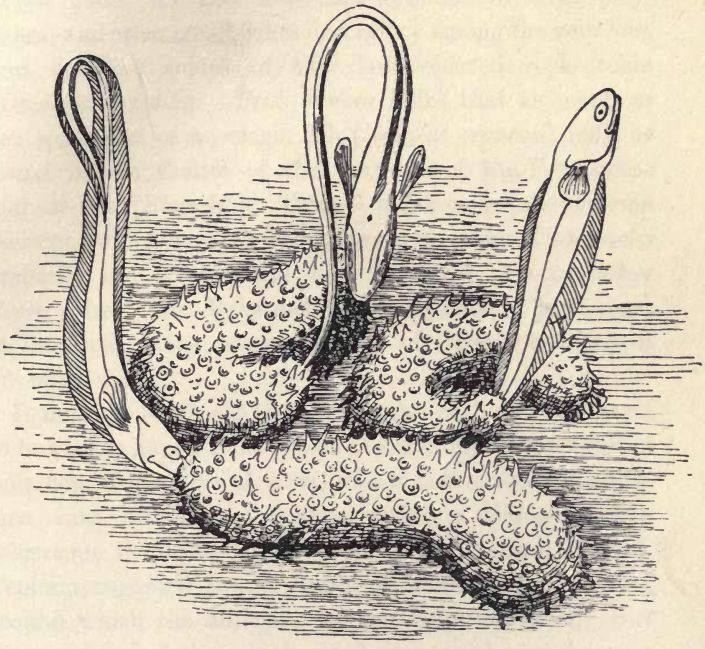


FIG. 48.—Fierasfer acus, entering and leaving Holothurians. (*After* Emery.)

it now insinuates its body into its host in a quiet leisurely way. When the Holothurian is placed in water with insufficient aeration, the fish comes out, and rises to the surface, taking in gulps of air.

Numerous small horse-mackerels (Carangidæ) swim about under the shelter of the umbrella of large jelly-fishes, and other small fishes find safety among the very long and hair-like spines of the dark-coloured rock-urchin (*Diadema saxatile*). Prof. Weber notes that as many as ten specimens of a pelagic fish (*Nomeus gronovii*) may be found in the shelter of the tentacles of the Portuguese Man-of-War (*Physalia*). There is a fish called *Amphiprion bicinctus*, which lives inside a large sea-anemone (*Crambactis arabica*), and Prof. Plate has described *Apogonichthys strombi*, from the Bahamas, which spends at least part of its time in the mantle cavity of large specimens of *Strombus gigas*.

It must be confessed that the hermit-crab does not seem to be always happy in its choice of a shelter. Prof. Chilton tells how *Eupagurus stewarti*, which has a straight abdomen, inhabits tubular cavities within a Millepore or a calcareous Polyzoon. The cavities may be due, as Prof. Benham suggests, to the decay of a branch of seaweed around which the Millepore or the Polyzoon grew. But the point is that the calcareous shelter may be much larger than the hermit-crab, and must be very heavy, if not too heavy, to carry about.

An intermediate state of affairs is illustrated when two animals share the same dwelling without sharing food. Thus the prairie-owl lives with the ' prairie-dog ' in North America, and another species of owl with the Viscachas in South America. Perhaps in the same category may be

ranked the 'Inquiline' gall-insects, which are not themselves gall-producers, but utilize what others make.

Another half-and-between case is that of a moth, *Galleria melonella*, whose caterpillars feed entirely on beeswax. The female lays her eggs on pieces of wax or wood within the hive; the minute grub-like caterpillars emerge in about eight days and make themselves a shelter of silk which protects them from the stings of the bees. They feed chiefly on old honeycomb. As they grow they enlarge their shelter into a gallery which opens on the surface of a comb. When they reach their limit of growth they make cocoons on the wall of the hive near the entrance, and pass out as moths in a fortnight or so.

Commensalism.—This term, which is just the same as companionship, 'eating at the same table', may be usefully restricted to external associations which are beneficial on one side at least. When the benefit is two-sided, the term 'mutualism' or 'commensal mutualism' may be used.

Many associations remind one of the beggar at the rich man's gate—a small creature living on the crumbs from its larger host's table. But it is difficult to draw the line between cases where the benefit is all on one side and those where some degree of reciprocity obtains. Thus Miss Winifred Coward has described a peculiar little hydroid, *Ptilocodium repens*, which grows among the polyps of a Pennatulid, *Ptilosarcus*, from the Timor Sea. The two kinds of animals live literally 'cheek by jowl', and as the hydroid has numerous defensive polyps, out-numbering the nutritive ones (which, it is interesting to notice, have degenerate tentacles), it may be that it confers some protective advantage on the Pennatulid on whose food-supply it levies toll.

A vivid description of the partnership between the giant sea-anemone and the 'painted fish' (*Amphiprion*) is given by E. J. Banfield in his delightful book *My Tropic Isle* (1910). The dainty fish, only an inch and a half long, is 'resplendent in carmine, with a broad collar and waist-band of silvery lavender (or rather silver shot with lavender) and outlined with purple'. On the least alarm the fish 'retires within the many folds of its host, entirely disappearing, presently to peep out again shyly at the intruder. It is almost as elusive as a sunbeam, and most difficult to catch, for if the anemone is disturbed it contracts its folds and shrinks away, offering inviolable sanctuary. If the fish be dissociated from its host, it soon dies. It cannot live apart, though the anemone, as far as can be judged from outward appearances, endures the separation without a pang'. What the fish does for the anemone is uncertain—perhaps it attracts small food. But other anemones greedily seize inquisitive fishes.

Many crabs and hermit-crabs form an external partnership with sea-anemones, which grow on the carapace, or sometimes on the forceps, or, in the case of some hermit-crabs, on the borrowed Gasteropod shell. The benefit is clearly two-sided, and a Crustacean bereft of its partner anemone has been known to search for it diligently. A hermit-crab shifting from its Gasteropod shell to a larger one has been seen trying to flit its partner as well. To the Crustacean the benefit is that the sea-anemone can sting, and that it also serves as a marking cloak. To the anemone there is the advantage of transport and of crumbs from its companion's table. Prof. Weber refers to cases like the crabs Polydectus and Melia, where the anemone is carried about on the forceps in a highly aggressive

way—the one animal literally making a tool of the other!

One of the most extraordinary cases of commensalism is that described by Colonel Alcock as established between an Indian Ocean hermit-crab, *Paguristes typica*, and a sea-anemone of the genus *Mamillifera*. The sea-anemone settles down on the hinder part of the young hermit-crab's tail, and the two animals grow up together in a most intimate manner, the spreading anemone forming 'a blanket which the hermit-crab can either draw completely forward over its head or throw half-back as it pleases'.

A very well-known association is that between a hermit-crab and a bright orange sponge, *Suberites domuncula*, which spreads over the Gasteropod shell which the hermit-crab has borrowed. The sponge is unpalatable to many animals; it is packed with strong needles of flint; and it has a pungent odour. For these reasons it must be of advantage to its bearer, which it also very effectively masks. It seems to dissolve away the Gasteropod shell, but this is probably no disadvantage, since it lightens the burden the hermit-crab has to carry. When the sponge settles down on the shell inhabited by a hermit-crab which has not reached its limit of growth, it will of course be left behind when the Crustacean flits. It is quite possible that the vacated shell with its associated sponge may be picked up by a smaller hermit-crab in search of a new shelter. The same sponge also grows on the back of *Dromia vulgaris*, a common crab, and some experiments made at the Naples Zoological Station by Signor Polimanti brought out two very interesting facts, first, that the crab takes the initiative in getting the sponge on to its back, planting it there itself, and second, that the sponge really affords its

partner an effective protection against the appetite of cuttlefishes. It is a fine case of diamond cut diamond, the thrust and parry between crab and cuttle.

A number of animals which clean up others without utilizing any living material should be ranked with the commensals, not with the parasites. This is true of many of the so-called fish-lice (Argulidæ), which are scavengers of the skin of carp and other fishes, and of various insects and mites (e.g. Trichodectes, Philopterus), which do the same for mammals and birds. Another example is the plover, which Herodotus accurately described as cleaning the mouth of the crocodile, removing leeches and other parasites from the huge gape.

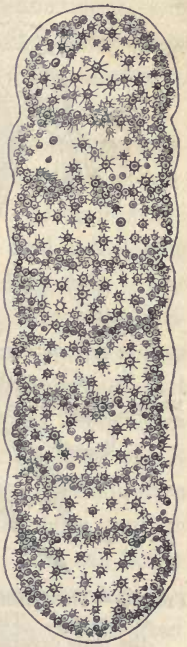


Fig. 49.—A colonial Radiolarian, *Collozoum inerme*. (*After* Brandt.) The small spheres are the units composing the colony; each is accompanied by partner Algæ; all are imbedded in a transparent matrix. Greatly enlarged.

Symbiosis.—It seems to us justifiable and useful to restrict this term to the mutually beneficial internal partnership of two organisms of different kinds.

In most Radiolarians—pelagic Protozoa usually with siliceous skeletons—there are symbiotic Algæ which used to be known as 'yellow cells'. They are unicellular plants embedded in the transparent living matter of the Radiolarians, and a very profitable partnership has been established. Being possessed of chlorophyll, the Algæ can utilize the carbonic acid formed

by the Radiolarian, and are able to build up carbon-compounds, such as starch. They give off oxygen, which is of course profitable for the animal, and they doubtless utilize nitrogenous waste products made by the animal. If things are not going well, it is always open to the Radiolarian to digest its partners! The huge numbers of Radiolarians—alike of individuals and of species—seem to indicate that the symbiosis is very profitable.

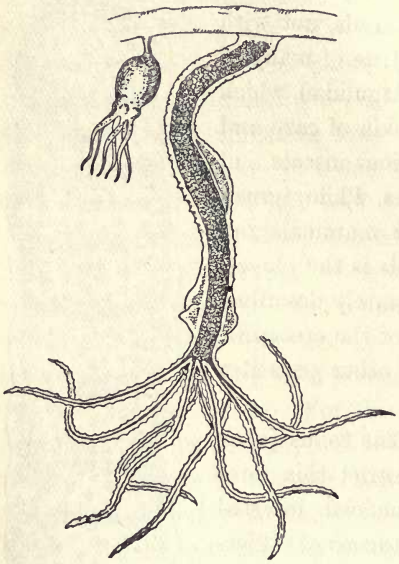


FIG. 50.—The Green Hydra, expanded and contracted. The expanded form shows the male organs or testes as swellings near the base of the tentacles and the ovary as a swelling near the attached base. The transparent ectoderm is seen as a layer surrounding the endoderm which contains the green elements, usually regarded as symbiotic Algæ.

The symbiotic Algæ are known as Zooxanthellæ, and their occurrence has been recorded in a variety of animals. In the Planarian worm Convoluta, they are very abundant and quite indispensable. Prof. Keeble has shown that the larvæ do not develop unless they are infected, and that an adult which has been driven by straitened circumstances to absorb its partners can be re-infected and given a new lease of life.

Besides the Zooxanthellæ there are other symbiotic forms, e.g. the green Zoochlorellæ. Their occurrence is known in Amoebæ (a colony of *Amoeba viridis* flourished for ten years without food), in the green Hydra, in the green freshwater sponge, in some sea-anemones, and in many Alcyonarians. They are usually referred to the family Palmellaceæ, but are not certainly known to live apart from symbiosis.

Lichens.—One of the most striking instances of partnership is that illustrated by lichens, which Schwendener, Bornet and other botanists proved to be compound plants. Each consists of the branching and interlacing threads of a Fungus, enclosing partner Alga cells. The Fungus fixes the plant, absorbs air, water and salts, protects the Alga from drought and injury, and forms spores which are wafted away by wind and water, and may start new lichens if they find their proper partners. The Alga uses the sunlight to build up carbon compounds, and it joins with the Fungus in forming sexual reproductive bodies. By taking proper precautions the Alga can be got to live in water without the Fungus, and the latter can live on sugary media or the like without the Alga.

The life of many a lichen is rather more complicated than we have indicated. Thus in many of those that grow on trees the Fungoid elements absorb decaying organic matter; and some tropical forms are actually parasitic, absorbing food from the living tissues of leaf and stem. In some cases the Fungus seems to kill its partners and absorb them. The Algæ are sometimes so much shut in from light and air that it is difficult to believe that they can do much in the way of photo-synthesis, and there is strong evidence that in such cases the Algæ

are able to feed upon oxalic acid, and perhaps other organic acids, produced by the Fungus. But after we allow for these and other complications, there remains no doubt that many lichens illustrate a very effective symbiosis or mutually beneficial partnership of a Fungus and an Alga.

A very interesting three-fold association has been investigated by Prof. Bottomley. Nitrogen-fixing Bacteria (*Azotobacter* and *Pseudomonas*) are found along with Blue-Green Algæ (*Nostoc* and *Anabæna*) in the thallus of the liverwort *Anthoceros* and in the leaves of *Azolla*, the Water Fern. The same combination of Bacteria and Algæ is found in the roots of Cycas. It may be that the Alga supplies the necessary carbohydrate for the Bacteria, and that the host-plant profits by the nitrogen-fixing powers of the Bacteria.

It is usual to find numerous Bacteria living in close association with animals—in the food-canal, in the mouth, in the lungs, in the tissues, and some experts have raised the question whether a higher animal could live a normal life without its internal flora. By ingenious carefulness M. Michel Cohendy, working at the Pasteur Institute, has been able to rear chicks to an age of forty-five days without their showing any trace of microbes. At that date they became too big for their antiseptic cage and had to be let out—quite healthy and vigorous. In about twenty-four hours those that were tested had the usual stock of microbes. As they stood the sudden infection quite well, it is plain that the power of resistance to ordinary microbes is inborn or constitutional, not an individual acquisition.

Just as there are friendly Bacteria in many animals,

which seem to help to oil the wheels, so yeasts may also be co-operative. An instance is given by Dr. Karel Sulc, who found various yeasts of the Saccharomyces (ordinary yeast) type living inside the accumulated reserve material of Aphides, Scale-insects, Cochineal insects, and the like. There is evidence that they are not passive inclusions, but that they work out changes in the stores.

In the interesting caterpillar of *Nonagria typhæ*, which feeds inside the stem of bulrushes, the digestive area is very restricted, and Portier could find no evidence of a ferment able to digest cellulose. But there were present in great abundance very minute organisms, which he calls ' pseudo-bacteria ', probably of the nature of moulds, which work at the vegetable tissue and break it down. They pass through the wall of the intestine and are engulfed by the caterpillar's amœboid blood corpuscles. The case is a very extraordinary one and must be re-investigated, but it looks like a genuine partnership, as if the ' pseudo-bacteria ' were middle-men between the animal and its food. We are reminded of the beautiful Infusorians which seem to be always present in the horse's intestine, helping in the breaking down of the hay and other foodstuffs.

The microbe (*Pseudomonas radicicola*) of the root-nodules of Leguminous plants occurs also in some members of other orders. Prof. Bottomley has found it forming nodules in the lateral roots of the bog-myrtle (*Myrica gale*), and has shown that young plants, grown in sterilized soil poor in nitrogen, do not flourish unless they have the root-nodules, and that root-nodules are produced on uninfected plants after they are treated with a culture of the microbe. Miss Spratt has also found the same form in an alder (*Alnus incana*) and in two buckthorns (*Elœagnus*

edulis and *Elœagnus rhamnoides*), and has proved its beneficial nitrogen-fixing rôle. It appears that the microbes are polymorphic, rod-like (bacillus) forms and spherical (coccus) forms being found in the same plant.

Parasitism.—When one organism lives in or on another —its host, gets its food from it, is inextricably bound up with it or with related forms, and is not beneficial but rather injurious in its influence, we speak of parasitism. But, as in other cases, the facts are too subtle for absolutely precise definition. There are beautiful Infusorians in the stomach of the horse, which are not found anywhere else; they apparently help rather than hinder the process of digestion: Are they symbions or parasites ? Many small Crustaceans are found on the skin of fishes, where they clean up mucus and the like; it is hard to draw the line between some of them and the barnacles on a whale's skin, which are merely epizoic. Not a few of the skin parasites, e.g. mites, are doing their best to clean their host. Many parasites seem to do no harm to their hosts unless these get out of condition; this is probably the case with many of the threadworms and tapeworms found in the food-canal of animals. Some parasites are quite unimportant unless they get shifted into peculiar situations, such as the vermiform appendix in man, within which Nematode worms often provoke inflammation, or unless they become suddenly very numerous. It need hardly be said that the definition of parasitism must be such as to exclude the antenatal life of the young mammal within its mother, for here the two creatures are of the same flesh and blood, and though the benefit is onesided and a drain on the mother, she is adapted to her offspring as no host ever is to its parasite.

Looked at broadly, parasitism is a way out of the struggle for existence. Just as some animals have betaken themselves underground or into caves or down to the great abysses, so others have become parasitic. It implies an abandonment of direct competition, and its occurrence at almost every level among backboneless animals shows that it has been frequently resorted to, and with great success, in many cases, as regards self-preservation and increase in numbers. It should be noted that in many parasitic types, e.g. among Crustaceans and Insects, only the females have adopted the habit, doubtless in relation to egg-laying and the protection of the offspring.

A thoroughgoing parasite, such as a tapeworm, is very effectively adapted to the conditions of its life. It is safe from all enemies (unless perhaps the practitioner with his vermifuge); it floats in a plethora of food, which it can absorb by the whole surface of its tape-like body; it can live and thrive with a minimum of oxygen, and it has a mysterious 'anti-body' which preserves it from being digested by its host; it has muscular adhesive suckers and, it may be, attaching hooks, so that it is safely fixed to the wall of the intestine; it lives in warmth and comfort without any expensive sense-organs to keep, with a low type of nervous system—a life of dull sentience. It has attained to what economists have called 'complete material well-being'.

The other side of it is, of course, degeneration. The tapeworm has a lowly developed nervous system, no sense-organs, slowly contracting smooth muscles, and so on. Only its reproductive system is highly developed, and even there a hint of degeneracy may be found in the self-fertilization that often occurs. For some of the tape-

worms and flukes are known to fertilize their own eggs. External parasites are naturally much less degenerate than internal parasites; the retrogression is proportionate to the thoroughness of the parasitism.

It is characteristic of parasites to be prolific. Some of the tapeworms are said to produce eight millions of eggs; the female Trichina gives birth viviparously to fifteen hundred young ones; a liver-fluke is said to produce some fifty thousand eggs. There are two ways of looking at this prolific productivity. On the one hand, as regards the individual organism, it is living without much exertion, with abundance of stimulating food at its disposal. It is physiologically in a position to be prolific. On the other hand, as regards the race, there can be no doubt that the prolificness is adaptive, that is to say, those types of parasite have survived which were constitutionally prolific. The risks in the life of a parasite are very slight when it is ensconced within its host, but they are often enormous in the juvenile stages, or when there is transference from one host to another. The life-history of the liver-fluke and the ox-warble, subsequently referred to, may be taken as good instances of these risks, but they are very general. It must not be supposed that the prolific reproduction was evolved as a reponse to these great risks; it is rather to be believed that those parasites which were constitutionally prolific have become the surviving parasites. There are good reasons for supposing that the parasitic alternative is always being attempted and has always been attempted, but that many of those organisms admitted to the available asylums have died out within them. The dog is known to have about forty different parasites; both man and the pig have more. The Scoter duck (*Œdemia nigra*)

harbours sixteen different species of flukes. Omnivorous animals in particular are peculiarly liable to become hosts of alimentary parasites. It is well known that oaks are used as hosts by many different kinds of gall-flies. In Europe, *Quercus pedunculata* harbours no fewer than ninety-nine different kinds of gall-flies, *Q. pubescens* seventy-nine, and *Q. sessiliflora* ninety-six.

Grouse Disease.—Writing in 1911 on *Grouse Disease*, Dr. Arthur Shipley said:

'Five years ago we knew two internal parasites (endo-parasites) and two or three parasites which live outside the skin (ectoparasites). At the present time we know that grouse, like other animals, have a considerable fauna living both in and on them. They are, in fact, not only birds, but in a small way aviating Zoological Gardens. The scientific members of the Grouse Disease Inquiry have recorded eight different species of insect or mite living either amongst the feathers or on the skin of the bird or in other ways closely associated with the grouse, and no fewer than fifteen animal parasites living in the blood, the alimentary canal, the lungs, or other organs. Some of these are negligible. They either exist in too small numbers or infest but a very small percentage of the birds; others, however, are found in about 95 per cent. of the cases investigated, and two at least are associated with grave disorders which often terminate in death'.

One of these is a Nematode worm (*Trichostrongylus pergracilis*), of which there may be 10,000 in one grouse, about equally divided between the two intestinal cæca, and a microscopic Protozoon, *Eimeria* (*Coccidium*) *avium*, which lives in countless numbers in the delicate lining membrane of the food canal in young grouse.

The almost transparent threadworm (*Trichostrongylus pergracilis*) of the grouse spends its early life on the heather.

'The eggs give rise to larvæ in about two days. The larvæ surround themselves about the eighth day with a capsule or cyst and undergo a "rest cure." After a period of quiescence they quickly change into second and active larval forms, which are minute, transparent, and quite invisible. These lead a perfectly free life, and in wet weather gradually squirm and crawl up among the leaves and flowers of the heather, where they remain until swallowed by the grouse. When once inside the bird, the larvæ make their way along the alimentary track, and enter the cæca, where they rapidly develop into adults'.

There are some parasites, such as the Liver Fluke and Trichina, which occur in numerous hosts, but this is the exception. The rule is that a particular parasite occurs only in a few, usually related, forms; and there are many parasites which occur only in one host, or only in two—one for the young asexual stage, and the other for the adult sexual stage. The reason for this restriction to particular hosts is that one and the same animal is not likely to be adapted to a variety of somewhat subtle environments. Moreover, where there are two hosts, the adult parasite can only occur in a host that comes into very close vital relations with the host of the young stages of the said parasite. Thus the bladderworm of the rabbit becomes a tapeworm in the dog that eats the rabbit; the bladderworm of pig's flesh becomes a tapeworm in man. A vivid instance of the narrow range of adaptability in some cases may be inferred from the fact that the larva of the liver-fluke cannot continue its life in Britain except within the particular species of water-snail called *Lymnæus trun-*

catulus or *minutus*; if it enters another species it is unsuccessful. Yet the same larva in some other countries is able to continue its life in other species of water-snail!

When an examination is made of the food-canal of a bird or mammal or other Vertebrate, which has not been previously studied, some new species of parasite is very generally found. There is a remarkable individuality in the parasitic infection of distinct types. This probably illustrates the rôle of isolation in assisting the formation of species. Just as there is an Orkney vole and a St. Kilda wren, and a distinct species of snail in each valley in Hawaii, so there are different tapeworms, flukes and threadworms in diverse hosts. In some cases, where the species of host are nearly related, the species of parasites seem also closely akin, and it should be asked in such cases whether the observed differences in the parasites are really fixed hereditary characters, and not individually acquired features induced by the slight peculiarities of environment.

There are curious little Crustaceans, called Lamippids, of the order of Copepods, which occur, for instance, in burrows among the spicules of Alcyonarian corals. They are very distinctive little creatures, characteristic in their buccal armature at one end and in their caudal fork at the other. They have been studied systematically by A. de Zulueta, who finds that each species of *Lamippe* has its particular host. Some hosts may harbour two or three species, but no species occurs on two hosts. It would be interesting to transfer some young Lamippids from their proper host to another, to see whether some of the alleged specific differences are not directly due to the immediate environment. Some of the species may be what we venture to call 'modification species'.

Parasites affect their hosts in a great variety of ways. Their injurious influence may be trivial or serious, direct or indirect. Skin parasites which are unimportant may prepare the way for the entrance of very injurious microbes. Intestinal parasites may become so numerous that they interfere with the host's nutrition; several hundreds of large threadworms have been taken out of a horse's stomach. They may cause very serious perforations of the wall of the intestine. In the well-known sturdie-worm of the sheep, the large bladderworm is found in the brain or in the spinal cord, and causes disastrous locomotor disorders, and often death. On the whole, however, the relation between parasite and host is remarkably unimportant, partly because of the adaptability of the organism, and partly because the very aggressive parasites have probably eliminated themselves from time to time by killing their hosts. Such a case as Ichneumon larvæ and caterpillars, referred to elsewhere, is only possible because the insect larvæ pass into a new phase of life after they have killed their hosts. The disastrous effects of parasites are usually the results of the infection of *new hosts* who have not become adapted to withstand the toxic and other deleterious influences of the intruders.

Of great interest are those cases first rightly interpreted by Professor Giard, where the parasite destroys the reproductive organs of its host, effecting ' parasitic castration '. Thus male crabs infected with the peculiar crustacean parasite called Sacculina have their whole constitution profoundly altered. The reproductive organ may be destroyed and a small ovary—producing ova—may take its place; the shape of the abdomen approximates to that of the female; and the protruding parasite is actually

guarded by its bearer as if it were a bunch of eggs. But we cannot do more than give a glimpse of this wonder of parasitism.

In Illustration

Liver-Fluke.—The well-known life-history of the liver-fluke (*Distomum hepaticum*) affords vivid illustration of the vicissitudes that are so common—especially, it may be noticed, in the case of parasitic animals. The adult lies, like a flat leaf, in the tributaries of the bile-duct of the sheep (and some other mammals), causing the disease known as liver-rot, which often does much damage among sheep. Like most internal parasites, it is very prolific, and it is peculiar inasmuch as it fertilizes its own eggs. The developing eggs pass down the bile-duct, down the intestine, and on to the ground. If they are deposited on quite dry ground, they soon die; if they come to rest on damp soil or among wet grass, they may remain in a state of latent life for a couple of weeks; if they fall into a pool of water, they continue developing. In a short time there emerges out of the egg-envelope a microscopic, somewhat pear-shaped, ciliated larva, which swims freely in the water. It has energy to continue swimming for about eight hours, but has no mouth or means of feeding. In the course of its swimming it comes into contact with many things, such as stick and stone, water-weeds and small animals, but it pays no heed to any until it happens to touch the little water-snail (*Lymnæus truncatulus* or *minutus*) into which it immediately enters, finding the breathing aperture a convenient door. If we could understand the memory of the living matter which enables this tiny brainless larva to respond effectively to the touch

of the only creature by which its development can be continued, we should have read a great part of the riddle of life. Inside the water-snail, the larva loses its cilia and two eye-spots which it had; it becomes a sporocyst which falls victim to precocious asexual reproduction and forms rediæ; the rediæ, which are larvæ of a second type with a food-canal and other complications, usually give rise

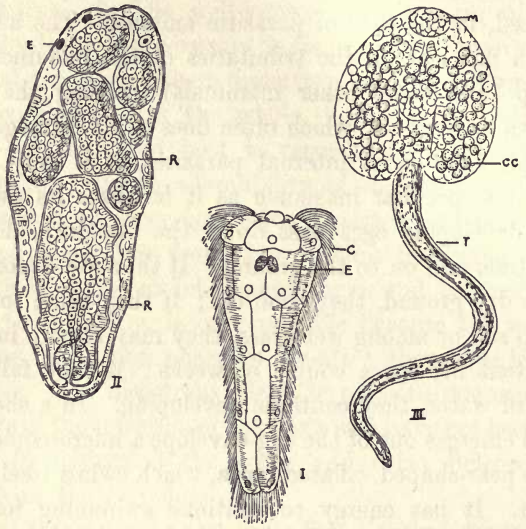


FIG. 51.—Three stages in the life-history of the liver-fluke (*Distomum hepaticum*). I. The ciliated free-swimming larva, with cilia (C), and eye-spots (E). II. The sporocyst stage, showing the internal asexual production of another kind of larva—the redia (R). III. The last larval stage, the cercaria, or young fluke, showing tail (T), cyst-making cells (CC), and the mouth (M). (*After* Thomas.)

to more rediæ; these in their turn produce—again asexually—a third type of larva, known as the cercaria, which has a bilobed food-canal, the beginnings of suckers and gonads, and a locomotor tail. The cercariæ leave

the moribund snail, leave the water, wriggle up blades of grass, and encyst themselves, losing their tails in the process. If a sheep pass that way and eat the blade of grass on which the cercaria is encysted, the life-history is continued, and it cannot be continued in any other way! From the food-canal of the sheep the cercaria, now a young fluke, migrates up the bile-duct to the liver, and there, in the course of a few weeks, becomes mature. In some cases the adult liver-flukes die in the liver after they have reproduced; in other cases they migrate out of the liver, are passed down the gut, and die on the ground. It will be noted that in this extraordinary life-history there is point after point at which the process may come to an end. The eggs may light on dry ground; they may develop in a pool without water-snails; they may exhaust themselves before they come across the water-snail; the water-snail containing them may be swallowed by a water-wagtail; the sun may dry up the encysted cercaria; or it may be that no sheep comes that way to eat the infected grass. The whole life-history is a passage over a Mirza-bridge with an exaggerated number of possibilities of failure. Had it not been for their prolific multiplication, the race of liver-flukes would long since have come to an end.

Sacculina.—The adult parasite which protrudes on the under surface of the abdomen of crabs, is a somewhat bean-shaped sac, consisting very largely of a brood-chamber distended with eggs. The central mass includes a nerve-ganglion, a cement gland which secretes the egg-cases, and the hermaphrodite reproductive organs. There is no trace of digestive or circulatory organs, but the stalk of the parasite is continued into the crab and divides into numerous 'roots', by which food is absorbed and waste

excreted. The animal is at the nadir of parasitic degeneration. But what of the life-history? Out of the brood-chamber there emerge Nauplius-larvæ, with three pairs of appendages, a food-canal, and a median eye. They feed and grow and moult, and pass into a second—the Cyprid—larval stage. These fix themselves, just like barnacles and acorn-shells (see page 448), by means of their first pair of feelers, to the back or limbs of young crabs, finding a soft place at the base of the large bristles or setæ. All but the head region is cast off; the structures within the head contract; eyes, tendons, pigment, and the remains of the shell are all lost, and a tiny sac sinks into the interior of the crab. Eventually it reaches the ventral surface of the abdomen, and, as it approaches maturity, the cuticle of the crab softens beneath it, so that the sac-like body protrudes. It seems to live for three years, during which the growth of the crab is arrested. The reproductive organs of both male and female crabs are destroyed.

Ox-Warbles.—What an extraordinary story is that of the ox-warble fly (*Hypoderma bovis*)! The eggs are laid on the skin and are licked off into the mouth. According to Jost, they hatch at the foot of the gullet, and the larvæ bore into its wall and wander about in it for months (July–November). They go on the march through the body, through midriff, connective-tissue, kidneys, and what not and come to rest beside the vertebræ (December–May). Subsequently they pass upwards by way of the connective-tissue of the back muscle to a position just below the skin of the back—the last chief place of their assembling. They occur here from January till July, when they emerge and fall on to the ground. They pass into the pupa stage on the ground and the winged fly emerges in a few weeks.

Some of the tales of parasites are grim, almost like nightmare imaginings. Roubaud has told us, for instance, of two species of fly (he called the genus *Chœromyia*) which live in the burrows of the Cape Ant-Eater and the Wart-hog. The adults live on dung and love darkness. The larvæ lie in the damp ground, able to endure prolonged fasting, biding their time. They are attracted to the warmth of their hosts; they emerge from the earth and fix themselves to the skin, piercing it and drawing blood. They can ingest three times their weight of blood. Roubaud reared one on himself, which reminds us that there is another fly of somewhat similar habit, *Auchmeromyia luteola*, whose larvæ pierce the human skin and suck blood.

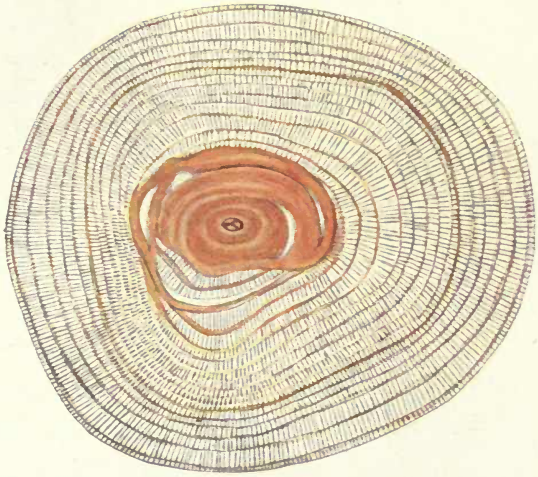
Fabre tells us of a pigmy black Chalcid fly which follows the giant Cigale, like a Nemesis, as she lays her eggs in the twigs. As soon as the Cigale has filled one chamber and passed on to the next, the anonymous Chalcid deliberately inserts her alien egg, which effectively undoes the larger mother's labours. For out of the egg comes a grub which devours the Cigale's eggs. 'A small, quick-hatching grub, richly nourished on a dozen eggs, will replace the family of the Cigale'.

How curious, too, are the facts of hyper-parasitism, where one parasite preys on another. The gall-fly *Charips victrix* seems to destroy a beneficial Braconid that preys upon plant-lice; another gall-fly, *Cothonaspis zig-zag*, destroys *Phora aeletiæ*, which is a parasite of the injurious cut-worm of the cotton.

A complication in regard to the theory of galls has arisen through the growth of scepticism as to the part which the so-called gall-making animals play. Most galls are believed to represent the plant's reaction to the secretions of the

larva which hatches from the egg deposited by the gall-making animal, and there can be little doubt that this is a true interpretation in many cases. But there are other galls which arise apart from insects and mites altogether, namely fungus-made galls, and it is a suspicious fact that there is often a striking structural resemblance between the animal-made gall and the plant-made gall. Therefore, Jules Cotte and others have suggested the theory that many so-called animal-made galls are due to moulds or bacteria or other fungi introduced by the animal. The insect or mite would thus be important not so much in itself, but because it carried a vegetable infection, and, as a matter of fact, many so-called animal galls are demonstrably associated with fungoid growths. Besides the frequent resemblance in structure between animal-made galls and fungus-made galls, there are other notable facts which Cotte utilizes in his argument. Animals far apart from one another are sometimes able to make very similar galls; the same animal may produce very diverse galls; an animal which causes galls at one place or at one season may be inoffensive at another; there is sometimes a puzzling disproportion between the dimensions of the gall and the number of its alleged producers; some galls continue to grow after the animal parasites have disappeared, and others are formed before the egg of the parasites hatches. In any case, we have another illustration of complex interlinking of organism with organism.

Pearls and Parasites.—It is well known that if a foreign body, such as a grain of sand, gets in between the shell of a mollusc and the underlying skin (or mantle) which lines it and makes it, fine layers of nacre may be deposited around the intrusion and a sort of pearl formed.



But these are not 'fine pearls'. The experiment has often been made of boring a hole through the shell and inserting a minute fragment of mother-of-pearl between the shell and the mantle; this makes a centre for pearl-formation, and a more valuable semi-artificial pearl results. Gradually it began to be suspected that the really fine clear pearls, with translucent centres, were formed around minute intruding parasites, which the skin of the mollusc imprisoned, somewhat in the same way as the oak imprisons the larva of a gall-wasp within an 'oak-apple'.

In 1902 H. Lyster Jameson showed that the agent in forming the pearls in the common Edible Mussel (*Mytilus edulis*) is the larva of a parasitic Trematode, which, instead of secreting a cyst of its own, as is usual with such larvæ, stimulates the mussel to form around it a sac of epidermal cells. These cells possess the same physiological properties as the outer shell-secreting epidermis, and eventually, on the death of the Trematode larva, secrete conchiolin and calcareous salts, which, deposited in concentric layers around the remains of the worm, become the pearl. But the life-history remains obscure. It is possible that the early stages of the *Mytilus* parasites live in the cockle (*Cardium edule*), where closely related forms certainly occur. It is possible that the adult form of the *Mytilus* parasite is to be found in the Scoter Duck, but the experiments made to test this have not yielded any conclusive result.

It has been suggested that the fine pearls of the Ceylon pearl-oyster are due to the larvæ of a tapeworm, *Tetrarhynchus unionifactor*, but the searching work of Lyster Jameson does not confirm this conclusion. There is no doubt that the young stages of this tapeworm occur in the pearl-oyster, along with pearls, but it does not follow

that the larvæ cause the pearls. It may be a case of two parallel diseases, comparable to the case of a dog infected simultaneously with tapeworms and mange. Mr. Jameson maintains that pearls arise round nuclei of some variety of shell-substance formed when the normal rhythm of secretion is disturbed.

A very careful study of the formation of pearls has been made by A. Rubbell in the case of a freshwater mussel *Margaritana margaritifera*, which is common, for instance, in some of the mountain streams of Bavaria. His observations are quite against the theory that pearls are sepulchres of flukes or any other parasites. He finds that they arise around minute particles of a yellowish substance, which resembles the outermost layer of the shell (the periostracum). The pearls are formed in closed, single-layered sacs of epithelium, which are constricted off from the external epithelium of the mantle, that is to say, the fold of skin which hangs down like a flap on each side of the bivalve, lining and making the shell. Growth takes place by the deposition of layer after layer around the yellowish centre. The coalescence of several pearl sacs may give rise to curious compound pearls. What are called 'shell-pearls' begin in the mantle and become secondarily attached to the shell; they are to be distinguished from shell-concretions which are formed around intruded bodies, and do not show any concentric layering. According to Rubbell, the innermost, or mother-of-pearl layer of the shell, is divided, at certain places at least, into an inner and an outer stratum by a clear intermediate layer, which is also seen inside the pearls.

It appears, then, that there are pearls and pearls. Keeping to those which are formed in 'pearl-sacs' of the

mantle, we may distinguish (1) those formed around an extrinsic solid inorganic nucleus such as a quartz particle; (2) those formed around an extrinsic organic nucleus, such as a parasite, an ovum, or a fragment of tissue; (3) those formed around a minute centre of the shell-forming organic substance, called conchin. Very interesting experiments have been made by Alverdes, who introduced fragments of tissue into the mantle or skin of mussels and found that they were surrounded by concentric layers of mother-of-pearl.

Domestic Complications

We have already seen that in some cases an animal cannot continue its kind without the unconscious assistance —we can hardly say co-operation—of other creatures. The mussel needs the minnow and the bitterling needs the mussel. But it seems almost necessary to separate off from such cases, where, after all, parental care is quite in evidence, such remarkable occurrences as the cuckoo's habit of handing over the responsibilities of nurture to a foster-parent. There is no more extraordinary story in the whole range of Natural History, and it becomes more wonderful the more we probe into its details.

Habits of the Cuckoo.—As Aristotle knew so many years ago, the European Cuckoo (*Cuculus canorus*), foists her several eggs, at intervals of a few days, into the nests of various more or less appropriate birds. These foster-parents, unconscious of being fooled, or indifferent to such considerations, hatch the cuckoo's egg among their own and feed the hungry self-assertive nestling at the expense of no small wear and tear, and at the

expense of eggs or offspring of their own, which the young cuckoo ejects from their proper cradle. 'The price of rearing every cuckoo is the total and invariable destruction of the offspring of the dupe'. The question that so many naturalists have asked is, 'Why doesn't the cuckoo brood'? Darwin accepted the answer that the parasitic habit was an adaptation to the fact that the mother-cuckoo lays her eggs, not daily as most birds do, but at intervals of two or three days. Since the American cuckoos, which build their own nests and rear their own young, have the same peculiarity of interrupted egg-laying, Darwin had further to suppose that these were just beginning to lose their nesting instincts—a view which the careful studies of Francis H. Herrick do not at all confirm.

The important facts in regard to the European cuckoo must first be recalled. The breeding range extends over a large part of Europe and Asia. In the autumn migration, the adults leave the young to migrate independently at a later date. The familiar Spring call is made by the male; the female's note is quite different, 'suggesting the sound of bubbling water'. She is polyandrous, for a time at least, there being five or more males to every female. Some authorities maintain that there is no true pairing.

It seems impossible to doubt that the bird used to build a nest and brood in former days, but there is no *certain* case of brooding cuckoos (*Cuculus canorus*). Careful ornithologists have spoken of the bird scheming, playing a trick, watching the result of smuggling her egg into the chosen nest, and even Baldamus writes: 'The female cuckoo, with or without a male, and either before or after

union, searches for nests of suitable nurses, and when found, watches them from the beginning of nest-building day by day, in order to choose the one most suitable '. As Herrick rightly points out, we must be careful in reading choice and motive into the bird's behaviour. On the other hand, we must not try to make an automaton of this remarkable bird.

The eggs of the cuckoo are relatively very small, they have thick resistant shells, they show an extraordinary variability in colouring, ranging from blue or blue-green, through speckled blue, brown, mottled or marbled brown and gray to nearly plain white. There is strong evidence that the same cuckoo, for a season if not for life, lays the same type of egg. In one particular good instance, among others, in the fine Fenton collection of eggs in Aberdeen University, eleven cuckoo's eggs taken in close proximity (from five different kinds of nests) are indistinguishable. In many cases the cuckoo places her egg in the nest of a bird with eggs similar in size and colour to her own, but in many cases it is quite otherwise.

It is doubtful whether this resemblance of the cuckoo's egg to that of the foster-parent is of any practical value. Herrick writes :—

' We should like to know how many of the 119 potential nurses of this bird would reject an egg of similar size, whatever its colour. We know that many birds will accept anything, especially after beginning to breed, while others will not. Some will try to incubate stones or potatoes. . . . The uniformly speckled eggs of the cowbird (*Molothrus pecoris*) fare only too well when contrasted with the snow-white eggs of the mourning dove, and the nearly white eggs of vireos, flycatchers, goldfinches and bluebirds.'

In most cases the mother-cuckoo lays her egg on the ground, then takes it in her bill, and then puts it as quickly as possible in a suitable nest. Baldamus and others have vouched for the fact that the bird sometimes lays her egg in the nest while sitting on the nest-wall. This is said to occur especially in the case of open and not too fragile nests. According to Baldamus the cuckoo lays five or six eggs at intervals of six or seven days; some observers state the intervals as two or three days. There is probably a good deal of variability in this regard, just as in the colour of the eggs.

The entire progeny of the cuckoo-nurse is destroyed. According to Jenner, Blackwall, Durham Weir and many others, the young cuckoo gets the egg or offspring of the foster-mother on to its broad depressed back, and climbing on the side of the nest ejects the rightful tenant. This effective dog-in-the-mangerish behaviour is probably, Herrick thinks, 'a reflex response to a contact stimulus of a disagreeable kind'. Blackwall made the significant remark: 'I observed that this bird, though so young, threw itself backwards with considerable force when anything touched it unexpectedly'. It has a convulsive hitching movement of legs and wings and body, which appears to be exhausting. The response dies away when the bird is ten to fourteen days old, after which anything is tolerated in the nest.

According to Baldamus and some other Continental observers, the mother-cuckoo, who may be accompanied by a male, occasionally removes the eggs of the nurse — which is the more remarkable since the cuckoo is not an egg-eater, but feeds mainly on hairy caterpillars and other insects. Baldamus also states that in nests which the

mother-cuckoo cannot readily reach 'the young of the nurse sometimes grow up, but are often suffocated or starved out by the young cuckoo, and are later removed by their own parents for the sake of cleanliness'. There is no doubt at all as to the accuracy of the British observations that the nestling cuckoo evicts the eggs or young of its foster-parent, but it seems that the evicting reaction is not always exhibited or is not always effective.

After the young cuckoo leaves the nest and has learned to fly, it is still attended by its foster-parents, who continue to offer food to their changeling. It could not be more 'spoiled' were it their child. Who can tell the inward spirit of the young cuckoo? But without maintaining that the creature is at all deliberate in its treatment of the rightful tenants of the nest, we cannot agree with those who write as if mental disposition were a negligible quantity. It has its fears, for instance, but how characteristically it 'expresses its fear', as Herrick says, 'in a manner calculated to inspire fear in its common enemies'. Jenner observed that long before it leaves the nest, the irritated bird 'assumes the manner of a bird of prey, looks ferocious, throws itself back, and pecks at anything presented to it with great vehemence, often at the same time making a chuckling more like a young hawk. Sometimes, when disturbed in a small degree, it makes a kind of hissing noise accompanied with a heaving motion of the whole body'. In the American black-billed cuckoo (*Coccygus erythrophthalmus*), which broods, the young birds give a similar expression to fear, but it occurs earlier and leads to a premature desertion of the nest—on the seventh day!

Some light on the problem is afforded, as Herrick has shown, by a study of the American cuckoo (*Coccygus*

erythrophthalmus), which nests and broods. It also has a tendency to produce eggs at irregular intervals (one to three days), so that there are eggs and young in the nest for a longer time than usual. Any disadvantage which might arise from this has been met by the fact that the young ones leave the nest in succession on the seventh day after birth, and thereafter spend a couple of weeks in a 'climbing stage' preparatory for flight. In this climbing the young bird, which has clambered or even jumped from the nest, moves about very effectively among the twigs. It grips the twigs very firmly with its feet and can hang head downwards fastened by two toes! 'It profits by the strength with which it was born endowed, and the exercise which it has received through the grasping reflex, for it is a perfect acrobat, and there seems to be no necessary feat of climbing of which it is incapable'. Herrick goes on to compare it to the young of the old-fashioned Hoatzin of the Amazons, which is also an adept climber; both use the bill to help the toes, but the Hoatzin has the advantage of having a clawed thumb and first finger.

Now the interest of this is that the American black-billed cuckoo shows something of the irregularity in egg-laying which the European cuckoo shows, and that it obviates a possible disadvantage by the peculiarity that the young bird leaves the nest very early, and has a remarkable climbing period during which it has a strong sense of fear. Prof. Herrick notes two other points: 'When disturbed in its nest-activities, the black-bill has been known to transfer its eggs to a new nest of its own, an action which strongly suggests the practice of the European cuckoo of carrying its laid egg to the nest of a nurse.'

'The American species occasionally "exchange" eggs,

or lay in other birds' nest, and when so doing the blackbill has been known to struggle for possession of the stolen nest'.

Prof. Herrick's general view is that the loss of the nesting instinct in certain cuckoos and cow-birds is due to an irregularity in the rhythm of the reproductive cycle. In most birds the parental instincts or the cyclical instincts connected with reproduction follow one another in a definite harmonious series 'with almost clock-like precision'—though modifiable at every point by intelligence.

The reproductive cycle is made up of a series of acts or chains of actions, which follow in a definite succession. Eight or more terms may be recognized, but the classification is unimportant, so long as it is observed that they are *serial* and *harmonious*, and that anything which profoundly disturbs their normal attunement is disadvantageous, and may lead to disaster. If the disturbance is of a fundamental and permanent character, new adjustments in the series must follow, if the species survive.

The cycle may be graphically represented by a number of nearly tangent circles, each of which stands for a distinct sphere of influence or for a subordinate series of related impulses as given in the simplified formula:—

1. Migration;
2. Mating;
3. Nest-building;
4. Egg-laying in nest;
5. Incubation and care of eggs;
6. Care of young in nest;
7. Care and 'education' of young out of nest;
8. Migration.

One term in the series may be weakened or drop out; another may be exaggerated and prolonged; there may

be ' blending ' and ' overlap ' of instincts, and many cases of individual disturbances are on record. A bird may build a new nest at the end of the breeding season; or it may build a supernumerary nest; or it may stop nesting and drop the eggs on the ground; or it may migrate too soon, leaving its young to perish. The most common failure is in the adjustment of nest-building to the time of egg-laying, and at this point ' parasitism ' arose. The lack of attunement between egg-laying and nest-building is casual in many birds, but it became more than casual in cuckoos and cow-birds. A modification of instincts ensued and a *modus vivendi* was arrived at. As to what started the lack of attunement, we can only say—' a nervous variation', such as all highly strung creatures frequently exhibit.

Jenner pointed out that the bird has but a short time to stay in its breeding area, and much to do in that short time. The gain of leaving the eggs to a succession of other birds is manifest. Other naturalists have indicated various advantages which make it easier to understand the *development* of the habit by selection, but leave the *origin* of the habit obscure, except that it is well known of many birds that they casually lay an egg in another bird's nest.

Many years ago we suggested, like Prof. Eimer, that the peculiar habit should be considered as an outcrop of a very peculiar constitution and character. That is to say, the non-brooding is not to be held apart from many other peculiarities of the cuckoo with which it is congruent. We referred, for instance, to the absence of any ' married life ', to the preponderance of males, to the polyandry that obtains, to the insatiable and gluttonous appetite, as well as to the sluggish interrupted egg-laying. That any

peculiar habit should be considered, not by itself, but in its setting along with the whole constitution and character seems to us still a sound proposition.

In spite of many suggestions, the puzzle of the peculiar habit remains, and Baldamus, who devoted his whole life to cuckoos, finished up his big monograph with the disappointing words: 'All answers to the wider questions of *how* and *why*, in my opinion, can be based only on conjectures: and, however clever many of these may be, for exact science they have scarcely any value at all'. It cannot be said, however, that this is true of the careful study of the behaviour of the cuckoo by Prof. Francis H. Herrick, of Cleveland, which we have utilised in the foregoing pages.

Animal Societies

Many animals form coherent colonies, by budding or by some form of division, the whole being physically continuous. Every grade occurs between mere aggregates, where the component units are closely juxtaposed but not intimately inter-dependent, as we see in many corals, and subtle integrates where the whole colony may move and behave as one creature, as we see in the free-swimming Portuguese Man-of-War (*Physalia*) or in the Fire-Flame (*Pyrosoma*). It is difficult to draw the line logically, but it seems clearer to keep the term colonies for those combinations where the bond of union is, in part at least, physical.

Many animals live together in companies, but without there being much or anything in the way of a corporate

life. Great numbers of sedentary animals may live beside one another, like daffodils by the lake side. Large shoals of herring, mackerel and other fishes may swim about together, and it is rather interesting that there are many different names for the various crowds. But association in numbers is not sociality. It will be found difficult, however, to draw a firm line, for many gregarious animals act together on occasions or may exhibit such devices as posting sentinels. There we see the first hints of societary life.

Crowds without Sociality.—The fiddler-crabs (species of *Gelasimus* or *Uca*) may serve as an illustration of animals living together in great numbers without there being any real sociality. They swarm on the mud-flats and estuary-shores near Manila, and in many similar places, —attractive and interesting creatures. One of the great claws of the male is enlarged out of all proportion, and is used as a weapon. According to Colonel Alcock, ' it is used as a signal to charm and allure the female ', but this view is not confirmed by the observations of Mr. A. S. Pearse at Manila. The males certainly dance about the females, but as they keep their backs constantly toward the females the great claw could not be seen. It is not used in burrowing or feeding ; in fact it seems rather in the way, but it is ' of unquestionable use to the male in his combats with his fellows and in defending himself from other enemies '. But our present point is simply that, although the fiddler-crabs live in great colonies, they show no communal life, except perhaps a certain playfulness. They are fiercely individualistic and very pugnacious. They make burrows and carry away the excavated material ; they close the opening with a plug

of mud when the tide comes in; they make a sort of 'preserve' of a circle, of a yard or so in radius, of which the burrow is the centre. 'Each fiddler', Mr. Pearse writes, 'researches the mud around his hole for food, and his hand is against every man. He is ever ready to dart into his burrow, and if danger threatens he quickly retreats into this refuge. If one of his fellows approaches too close to his domain, he rushes forth and enters into fierce combat. Each crab makes his hole the centre from which all his activities are conducted, and he treats the approach of any intruder as an unfriendly act'. The plugging of the burrow when the tide comes in serves as a protection against fishes and snakes and other enemies which hunt at the edge of the advancing tide.

Mr. Pearse points out that several circumstances might be held as favouring the development of some social life, but it is evidently not consistent with the Crustacean constitution. The mothers carry the eggs and young for a time, thus having opportunity to start a colony with them. The aggressive ways of the males might enable stronger individuals to gather a number of females about them, but there is nothing of this sort. The fiddlers live in enormous colonies, but there is nothing in the way of combination or co-operation—rank individualism obtains throughout.

The distinctive features of animal societies will become clearer as we consider particular illustrations; it is enough at the outset to recognize that an animal society is not physically continuous like a colony, and that it is more than a gregarious association. It means a community of separate individuals with more or less of a corporate life, and with the power of acting as a unity.

The Ant-Hill.—When we look at an ant-hill with its multitudes and their industry—without haste and without rest—we feel at once that the spectacle before us is very different from that presented by the crowd of mites in an old cheese. It is not a mere association of huge numbers, it is a community. Let us look into the matter more closely.

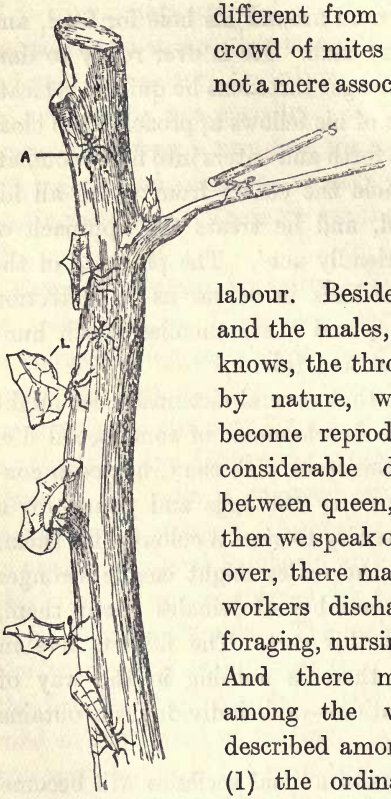


FIG. 54. — Leaf-cutting ants at work, Atta discigera. A, an ant without a burden; L, an ant with a leaf; S, an ant with a piece of stem. (*After* Moeller.)

The ant community shows division of labour. Besides the queens or mothers and the males, there is, as every one knows, the throng of workers—females by nature, who do not normally become reproductive. There is often considerable difference in structure between queen, male and worker; and then we speak of polymorphism. Moreover, there may be several castes of workers discharging different tasks—foraging, nursing, fighting, and so on. And there may be polymorphism among the workers. Thus, Bates described among the leaf-cutting ants, (1) the ordinary workers with relatively small heads, (2) officer-like individuals with large bald heads, and (3) another type with a twin simple-eye in the middle of the forehead—three forms different from one another within one species.

Another outstanding feature is the instinctive socialization. Put it as one may, there is no getting round the big fact that these ants have to a very large extent given up working for their own hand. While they satisfy their own needs by the way, the bulk of their energy is expended *pro bono publico*, for although we may not be justified in saying that they toil and moil consciously for the sake of anything, it is certainly not for themselves that they are so indefatigable and persevering. Noteworthy is the fact that in some ant-communities it seems to be a convention —an unwritten law—that if an 'empty' ant applies to a full one for food, he must forthwith be fed. This is carrying out the idea of community of goods to its utmost limit.

The capacity for unified action is well illustrated by the battles between rival ant-hills, and by the slave-making raids in which the pupæ of another species are captured and brought home to grow up into servitude. In some cases the slave-keeping has gone so far that the economic stability of the community depends solely on the enslaved species, with whom the fundamental business of production rests. The final result may be that the 'masters' seem to become enervated and unable to fend for themselves. In the well-known instance of the Amazon ant, *Polyergus rufescens*, the 'masters' have to be fed by the 'slaves'. Very curious also is the fact that in the raids the old slaves take their share in capturing new ones.

Co-operation in dragging a burden is a familiar sight and illustrates the socialization of the ant. But there are many subtler cases. Prof. Bugnion of Lausanne has corroborated many of the older observations on the tailor ant, *Œcophylla smaragdina*, which is common in hot countries. He vouches for their extraordinary habit of

using their silk-secreting larvæ (they have no silk themselves) as needle and thread when they are binding leaves together to make a nest. We have here an anticipation of the child labour of the early part of the industrial age!

The story reads like a burlesque, and it surely makes it difficult to accept the opinion of some naturalists that instinctive behaviour is unaccompanied by any awareness of meaning or feeling of the end. Whenever this difficulty is obvious, it is customary to say that intelligence has for the time being taken the reins. In any case, the *facts* are wonderful enough.

An eye-witness, Mr. L. G. Gilpin-Brown, writes from Ceylon :—

'Sometimes one will see an ant, with a larva in its mandibles, stalking aimlessly about on the outside of the nest. It stumbles on a small hole. It proceeds to study that hole, walks all round it, walks over it, and eventually decides that it really *is* a hole, whereupon it proceeds to business. Feeling round the edge with its antennæ it dumps the head of the larva on one side so as to fasten the thread of silk there, moves over and fastens it down on the other side, comes back again, and so on; each trip leaving a thread of silk behind, until the hole is completely sealed up.'

The tailor ants nest in trees and they sometimes find it difficult to bring two rather distant leaves close enough together to be sown. Then, as Bugnion relates, they have recourse to a perfectly extraordinary co-operation. Five or six will form a living chain to bridge the gap. The waist of A is gripped in the mandibles of B, who is in turn gripped by C, and so on—a notable gymnastic feat. Time does not appear to be of much account, but they work

definitely towards a result, and many chains may work together for hours on end trying to draw two leaves close to one another. We could not have a better instance of social co-operation.

The foundation of a new ant-colony takes place in various ways. After the nuptial flight the males die, and the females that escape the numerous pitfalls take refuge in crevices in the ground and lay their eggs. Janet has shown that the muscles of flight degenerate and break up after their use is past, and it seems that the material serves for the nutrition of the mother at this critical time. In *Atta sexdens* and some other cases, Piéron points out that the provident female carries with her a supply of the mycelium of an edible fungus on which she and her offspring afterwards subsist. When the earliest workers are hatched it may be necessary to sacrifice some of the eggs to keep things agoing.

Sometimes the fertile female utilizes a deserted nest of some other species, or sneaks into a tenanted nest. Sometimes the home of a small species is as it were grafted on to that of a large species, which it plunders. Sometimes the fertile female, falling near her old home, or the nest of the same species, is joined by workers who help her to start a new nest. Sometimes the workers of another species will receive a fertile female into the nest, with the result that their own queen abdicates, or is killed, or shares the honours with the new-comer. Very curious are the cases where a warlike queen enters a foreign nest, drives off the adult tenants, and establishes herself as foster-queen of their undeveloped progeny.

The way in which a new colony is started has a good deal to do with the economy that is established. It may

be quite sufficient in itself—the workers discharging all the tasks of food-getting, nursing, building and fighting. When a mixed nest has been formed, the workers may become semi-parasitic (as in the small *Solenopsis*), or may be treated as the guests of the other species. This leads on to slavery. But strangest of all are those cases where there are no workers at all, but only males and females. The fertile queen may be received into a foreign nest, and the rightful queen may be killed instead of the intruder. But this means sooner or later the end of that nest, for there can be no further production of workers.

According to M. Piéron the primitive mode of nest-founding is that in which the female is able to do it all by herself. This is illustrated by *Formica fusca*, which is probably an ancestral species, being indistinguishable from *Formica flori* of the Baltic amber. A second stage is exhibited in *Formica rufa*, where the female is unable to found her nest unless she gets help from friendly workers either of her own or of some different species. Then follow, in great variety of detail, the various stages of parasitism and slavery.

Among the many remarkable facts concerned with the founding of a new colony, let us call attention to two of the strangest. When a fertilized queen finds a suitable shelter and begins to lay, she often has to eat a few of her own eggs—to keep agoing. The others hatch into workers, who are soon able to help the mother. But more eggs may have to be sacrificed. If the female falls into a nest of her own kind, she lays her eggs there, and the workers tend the larvæ carefully. But Miss Adele Fielde has shown that if the tips of the workers' antennæ are snipped off they

do not look after the larvæ! They require some gustatory reward for their apparent altruism.

It is instructive to notice M. Piéron's general conclusion that, as ant-evolution becomes more complex, the members of the community become more and more dependent on one another. The species which are most thoroughly self-sufficient are the most successful species, as far as numbers and distribution are indicative of success. On the other hand, those that show slave-keeping and parasitic habits have smaller numbers and sparser distribution. 'It is evident that when ultra-civilization degenerates into slavery and parasitism it is neither good for man nor ant'.

The records of studies on ants make quite a good-sized library, but we have looked into the ant-hill enough for our purpose of illustrating some of the features of an animal society—division of labour, subordination of the individual to the whole, a capacity for unified action and co-operation. As we have had to say so often, the more we know about it the more the wonder grows. The social life seems so intricate that we wonder how it could have evolved at all. Yet let us look at it in one of the simplest expressions. There is a Mediterranean ant, *Aphœnogaster sardoa*, which illustrates what may be called an incipient societary form. According to Dr. Krause-Heldrungen these ants live in holes in the ground and do not build. Nor do they store or entertain guests. Huddling together is their form of sociality. They form living balls, ant interlocked with ant by the mandibles and tarsal joints, and they hold the eggs, larvæ, and pupæ in the middle. It is almost like a diagram of a primitive society and certainly matriarchal! A ball consists of three hundred to a thousand

individuals ; males have not been found ; and the investigator found only one queen. In winter the ball is very stiff and is slow to relax when it is unearthed. The whole communal life is summed up in huddling together. In summer, however, the ball is naturally more plastic, it is always being unmade and remade.

When we apply a term like ' social instinct ' to ants and the like, we are probably quite accurate if we mean that they have a hereditary disposition to act in concert, but there is a danger in the term since we also speak of our own ' social instincts ', meaning something much more complex than the ants. But in avoiding the Scylla of anthropomorphism, it is unnecessary to fall into the Charybdis of mechanism. For ants have a good associative memory, they are able to profit by experience, they act co-operatively and they are born with a predisposition towards social action.

There is no doubt that smell counts for much in the ant community. Each species seems to have its characteristic odour, just as the Chinese say of the English, who appear to them to smell of sheep. It is by the scent that the intruding ant is detected, but if it has been steeped in an essence made from the species into whose nest the experimenter introduces it, then it is welcomed. This does not in the least indicate automatism of behaviour ; it is an ' upsetting ' experiment such as might baffle even a clever dog. The mistake corresponds to that made in mankind when disguise appealing to the visual sense is almost perfect.

While it may be erroneous to speak of the members of the ant-hills being ' animated with a common purpose ', and while there is a good deal of individualism on the sly, it appears to us to be going to the opposite extreme to see

in the co-operation, e.g. of sewing two leaves together or of carrying a heavy burden, nothing more than the 'coincidence of purely individual activities'. Of course the activities must be individual, just as in a human society, but they may be combined in a joint enterprise whose result is for the benefit of the community rather than of the single life.

Termites.—Parallel to the true ants in their social life, very divergent in almost every other respect, are the so-called 'white ants' or Termites of warm countries—Africa, India, Australia, etc. They are usually referred to the order Neuroptera, whereas the true ants are Hymenopterous. While there is great variety in their social organization, it may be said that the Termite community usually consists of (1) workers, (2) soldiers, and (3) the reproductive individuals, or kings and queens. In most cases there is but one mature royal pair, around which the life of the community centres; but numerous young 'kings' and 'queens' are produced, which are winged and leave the termitary after a few days in great swarms which often come to nought. The mature 'kings' and 'queens' lose their wings. The organization is complicated in various ways, for instance by the occurrence of what Grassi called complementary kings and queens, which the workers keep in reserve lest anything befall the reigning pair. They are kept in a somehow inhibited state of development, but can be brought up to the reproductive level in a short time.

The workers illustrate arrested development; they may be regarded as 'permanent children' of both sexes, whereas the workers among ants and bees are all arrestments on the female side.

The soldiers are quite like the workers when they are hatched, but, while they also suffer arrestment, they develop on a line of their own with very large heads and jaws. It is noteworthy that the soldiers of different species differ much more than the workers do, and that there are no transitional forms between soldiers and workers. It must also be noticed that the title 'soldiers' is in many cases at least a courtesy title, for the workers usually fight much better and the militariness of the 'soldiers' is often exhausted in looking on!

The erection of a substantial and enduring termitary must, we think, have had great significance in the evolution of the complex Termite community. For it is a permanent product outside the organism, part of the social heritage, enregistering customs. It is often strong enough for a man to stand on, and it shows considerable complexity of architecture. There is the outside wall, with passages in it, and sometimes tunnels in which fungi are grown; there is the royal chamber where the king and queen are imprisoned; there is the nursery—a well-ventilated apartment sometimes—where the young are reared; there are store-chambers, ventilating shafts, cellars underground, and sometimes an eerie chamber where the reserve 'kings' and 'queens' are kept. One of the most interesting features has to do with the method of construction, for in many species the scaffolding of chewed wood is made first, the filling in comes next, and there is a final smoothing and pointing.

The industry of the community is prodigious. In many cases there is no resting by day or night, and we cannot find any parallel except in some highly evolved urban conditions where we have shops and restaurants and even

factories that never close, but go on night and day without ceasing. In most cases, the night is the busiest time, for Termites are distinctly nocturnal.

Enumeration is always interesting. Messrs. Andrews and Middleton counted the comings in and goings out with great patience.

'In one case the number of Termites going into the nest each hour varied from 1,702 between 1 and 2 p.m. to 8,100 between 2 and 3 a.m., while in the same case the numbers going out of the nest were 1,194 between 12 noon and 1 p.m. and 6,820 between 1 and 2 a.m.'

Thus the traffic in the arcades of the termitary is greatest in the middle of the night, and least at noon.

Very striking in the Termite community is the specialization of reproduction. It is practically left to the royal pair. In some cases there are several royal pairs. They alone are reproductive ; all the thousands of other members are productive and protective and domestic. The queen is like a grotesque caricature of fertility. As Smeathman observed, the abdomen becomes dilated with eggs until it is 'fifteen hundred or two thousand times the bulk of the rest of her body, and twenty or thirty thousand times the bulk of a labourer'. 'It is always protruding eggs to the amount (as I have frequently counted in old queens) of sixty in a minute, or eighty thousand and upward in one day of twenty-four hours'. Yet associated with this fertility is an equally surprising longevity, for the queen may live for several years. The male's tenure of life is unknown.

Another fact worth thinking about is the convergence in some details between the ant community and the white

ant community. In both we find the curious entertaining of other insects as guests and pets; in both we find the growing of fungi for food. Some Termites make a sponge-like maze of chewed wood and a mould is grown on the walls of the tunnels which is greatly enjoyed by the cultivators. It probably supplements their other food, supplying some constituent otherwise lacking or scarce.

Signalling among White Ants.—It has been known for a long time that the soldiers of some kinds of Termites are able to give an alarm-signal when they are frightened or distracted. Thus, as far back as 1779 König described *Hodotermes convulsionarius* striking dry leaves with its mandibles. Smeathman, Haviland and Sjöstedt have also reported the occurrence of indubitable signalling. Smeathman watched the building of the wall of a termitary, and noticed that soldiers standing on guard struck the building with their mandibles at intervals of one or two minutes and made a sort of crackling noise. This sign seemed to encourage the workers to increased industry, and to reassure them in some sort of way. When an attack was made on the ant-hill the workers disappeared into the internal passages and the soldiers made a sortie. After things were settled up again, the workers returned to their labours, and the sentinels to their signalling. Prof. Escherich relates that when he was having a Ceylon termitary of *Termes bellicosus* opened with a pickaxe, he heard a protesting noise from within—like that made by a rattlesnake. The noise was also heard by the native who wielded the instrument. He heard it and fled, leaving Escherich to continue the operations.

When Prof. Bugnion and three others were recently exploring in Ceylon, moving cautiously amongst dense

vegetation, they began to hear a curious rustling noise which at first suggested the presence of a cobra. Advancing carefully they found no hint of any snake, but traced the sound to a colony of *Termes obscuriceps* which had formed its galleries on the large fallen leaves of a Bread Tree (*Artocarpus*). The sound was caused by the Termites striking the under-surface of the dry leaves. On another occasion about a hundred Termites took possession of a little desk in Bugnion's office, and they used to answer back to knocks from without.

What is it that happens ? Prof. H. von Buttel-Reepen helped Bugnion in the inquiry, and showed what one has to do to make the white ants signal—' pour faire parler les Termites '. Part of a termitary is placed on a platter and covered with a sheet of strong, firm paper. The soldier Termites collect on the under-side of the paper and answer back to every signal. Whenever the paper vibrates they strike it repeatedly with their mandibles or with their chin (the basal piece of the third pair of mouth-appendages, which is exaggerated and hard in the soldiers). What happens in nature is that dry leaves or the like, struck by repeated blows, repercussate like resonating plates. The thin wooden partitions in the interior of the termitary will also have the same capacity of transmitting vibrations. It seems that the sound produced differs considerably in different species. To different audiences it suggested the hiss of a snake, a crackling, a rattling, and the far-off chirping of a cricket. It is characteristic of soldiers of the genus *Termes* and is always due to minute blows on a resonating surface. It is well illustrated by the Indian *Termes estheræ* (the same as König's *Hodotermes convulsionarius*), which makes long horizontal

galleries, with fungus-growing labyrinths, but no hills. The soldiers are very large and aggressive, and when disturbed make a prolonged noise like the crackling of withered leaves when one treads on them. It is produced by raining tiny blows on the dry surface of the fungus-labyrinths.

This type of signal is to be distinguished from another kind, a soundless signal, by which the soldiers seem to give orders to passing workers. The insect, firmly poised on its legs, with the head raised and the body slightly oblique, shakes itself for an instant convulsively. It signals with a shiver. This is probably very common among Termites, and is particularly well illustrated in *Eutermes*, a genus in which the structure of the soldier's head is not suited for drumming. It need hardly be said that the signalling noise, which is of much psychological interest, is not to be confused with a more commonplace sound—of minute grating—which is often heard in the silence of the night. That is the sound made by the Termites as they chew.

If the signals of the soldier-Termites are to be effective, they must be heard or felt, and this is borne out by observations in the field, by the answers that the tenants of Bugnion's desk made to taps from without, and by the anatomical demonstration of a well innervated organ which is probably peculiarly sensitive to vibrations. That the signalling is signalling seems indubitable, and it must be regarded as analogous not so much to the love-signals of the death-watch, who taps on the wainscot, as to the thumps on the ground by which rabbits indicate the approach of danger.

The Bee-Hive

We are probably nearer the truth in thinking of the bee-hive as a large family rather than as a society, but this makes little difference, for whatever the nature of the communal life may be it is certainly far away from anything human. It is run on predominantly instinctive lines, whereas a human society is predominantly intelligent. Comparisons between the bee-hive and the city are apt to be fallacious analogies.

So much has been written in regard to the life of the bee-hive that we shall not do more than call attention to a few essential features. It may be more useful to consider the question of evolution.

As every one knows, the hive shows polymorphism. There are the fertile females or queens; the males or drones; and the sterile females or workers—a sort of third sex. These three types differ in many details, and it is noteworthy that since the drones develop from unfertilized ova—having a mother but no father—their inheritance of male reproductive organs and masculine secondary characters must be handed on through the queens. Besides the structural polymorphism there is considerable division of labour. The queens and drones are wholly reproductive; the workers may be foragers, who go afield collecting, or nurses who attend to the queen and the young. The workers have finely developed brains, better than those of the queen, probably because more exercised, and they are distinctively females, being occasionally fertile. Both queens and workers develop from fertilized ova, the difference in result apparently depending on the quantity and quality of food given to the grubs. In short, every worker is a potential queen, arrested at a

certain point as regards her reproductive system. A notable fact is the short life of the individual workers, who only last two or three months in the arduous summer; their brain-cells show signs of chronic fatigue and pass eventually beyond the limits of recuperation. This is the seamy side of the bee's much-praised industry. With all its getting, it gets not wisdom, but foolishness.

Three events are alike remarkable—the nuptial flight, the swarming, and the death of the drones. In the nuptial flight, a young queen, arrived at her maturity, passes from the hive followed by a number of drones. One of these is successful in overtaking her and in fertilizing her. In many cases he will be the most vigorous and effective, which will be the better for the race, for while he and all the others perish, he is the father of another generation, while they have lived and died without having done anything but feed and fly. The store of sperms received by the fertilized queen-bee may last for a year or two, and it depends on the way in which she lays her eggs whether they are fertilized or not.

The swarming illustrates an interesting solution of the population question. When the numbers in the hive have greatly increased, the old queen goes off with the superabundance of the population, and founds a new community. It occasionally happens that this settles down in an impossible place and comes to naught, but Bonnier describes a successful nesting in a tree—a very interesting case, since the making of the combs had to be greatly modified to suit the new conditions.

The mortality of the drones is partly due to the shortage of supplies towards the end of summer, for they depend on what the workers give them, and the stores are, of course,

inviolate. The number of drones is also reduced, as we have just noted, by the nuptial flight. But there remains for the survivors—whether adults or larvæ—a tragic death at the hands of the workers and nurses. As the result of this Lycurgan tragedy there are no drones left at the end of the season. It seems rather noteworthy that while the venom of a cobra is not deadly to another cobra, the formic acid of the bee's sting seems to be fatal to another bee.

Evolution of Social Bees

Let us inquire into the evolution of social bees, utilizing especially the studies of Dittrich and Buttel-Reepen. The social mode of life is marked, as every one knows, by three distinctive features: (1) the differentiation of fertile females (queens) and normally non-fertile females (workers); (2) the utilization of wax for some kind of comb; and (3) the accumulation of stores, especially of pollen and nectar. Between the highly evolved social life of the hive-bees and the life of the solitary bees there are many transitional stages, and although we cannot display the pedigree of the hive-bee, nor arrange the stages in what was the actual historical sequence, we can see how very gradual the transition from solitary to social may have been. The following is Dittrich's series :—

I.—Bees living alone :—

(*a*) The mother dies after egg-laying and providing food for the larvæ, but without ever seeing the brood.

1. The nests are formed quite apart : *Prosopis*, *Ceratina*, *Osmia papaveris*, etc.
2. The females work independently, but the nests are formed in colonies, and there may be mutual aid

against attack: *Andrena*, *Anthophora*, *Chalicodoma*, *Osmia*, etc.

3. Females, or females and males, hibernate in companies: *Halictus morio*, *Xylocopa*.
4. Two or more females use a common hole of refuge: *Panurgus*, *Halictus*, etc.

(*b*) The mother survives to see the brood and watches over the nest.

5. *Halictus sexcinctus*.
6. The cells form a comb, *Halictus quadricinctus*.
7. The first-born young are all females, they work in the old nest, and parthenogenetically produce males and females: *Halictus scabiosus*.
8. The next stage, according to Buttel-Reepen, should be that in which the mother and the parthenogenetically reproductive young work together in the old nest, but a representative of this stage has not yet been found.

II.—Bees living socially:—

9. The fertilized female hibernates alone; forms in Spring a new nest; is helped by a brood of workers which are parthenogenetically reproductive only in isolated cases; and produces in the course of summer males and more females. In autumn the whole society dies off except the fertilized females: Humble-bees.
10. Permanent societies, with imperfect combs: the tropical species of *Melipona* and *Trigona*.
11. Permanent societies, with perfect combs: *Apis mellifica*, *A. dorsata*, *A. florea*.

This very interesting series does not of course disclose the impulses which led from one mode of life to another,

but it does show how gradually the state of affairs in the hive-bee community might evolve. This becomes even more convincing when we go into detail; thus, among humble-bees, some (in the North) are quite solitary—female and males, without any workers; some (e.g. in Britain and Germany) form temporary summer societies; some (e.g. in Corsica and the Balearic Islands) partially survive the winter as societies; and, finally, some tropical forms (according to R. von Jhering) are permanently social.

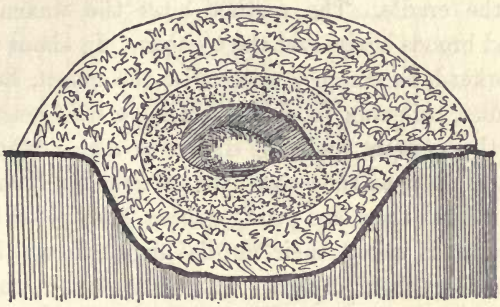


FIG. 55.—Section of nest of Humble-Bee, Bombus lapidarius. (*After* Wagner.) To the outside there is a felt work of grass stems and the like. The entrance is to the right on the level of the ground. In the middle of the cavity of the nest of this species, lies a dome of wax, above but not below the cells which contain the pupæ. The entrance is shown by which the queen—still the only tenant—enters to brood over the cells or to give honey to the larvæ. In a finely made nest the roof of the cavity of the nest is plastered with wax, where the figure shows a dark line.

We have figured a stage in the history of the nest of the humble-bee (Bombus). In the early Spring the queens, who are the only survivors of the previous summer's colony, awaken from their winter sleep, and make for the early flowers, such as the catkins of the dwarf willow. Each seeks out a nesting-place underground, perhaps in the

deserted burrow of a field-mouse. In the middle of a ball of grass, leaves and the like, some nectar and pollen are collected, and on this floor a cell or cradle of brown wax is built. Some eggs are laid in it and a lid is put on. The queen broods over this cradle, till in four days or so the grubs emerge. These soon use up the food in the cradle and more has to be put in through a hole in the lid. Moreover, the cradle has to be enlarged, till it is as big as a walnut. In about a week after hatching, the grubs pass into a quiescent pupa-state within papery cocoons, upright within the cradle. The mother bites the waxen walls away and broods again over the cocoons. In about twelve days worker-bees emerge, who assist the queen, building new cradles, collecting food, and nursing a new generation. Besides the workers there are drones or males, who leave the nest as soon as they can fly and fend for themselves outside. Then there are young queens, who fly off by and by on what is called their nuptial flight, in which they are joined by the drones. They are the mothers of another year.

As a single instance of more elaborate construction we have inserted a figure, from Janet, of the paper nest of a wasp (*Vespa media*). The nest in this case was hung to a leaf, but to begin with to a twig seen in the centre. The door is to the left side below. The walls are made of numerous (eighteen) overlapping envelopes of the chewed wood which forms the wasp-paper. About ten of these have been torn away below to make room for the combs. The first comb (2) was about four inches in diameter, and showed five concentric areas of cells, some the cradle of one young wasp, others used twice, mostly for workers, but partly for males. An axial support (3) leads

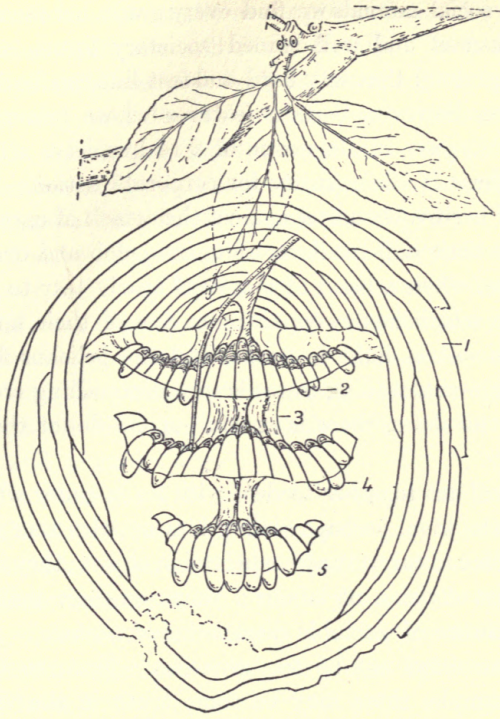


FIG. 56.—Nest of a Wasp, *Vespa media*, in vertical section. 1. One of the outer envelopes. 2. A cell of the first comb. 3. The axial support. 4. A cell of the second comb. 5. A cell of the third comb. (*After* Janet.)

to the second comb (4), which shows cells of various sizes. Another support leads to the third comb (5), which bore thirty-three cells for queens and seven for males, but was not completed peripherally. The original queen had disappeared; the nest included about thirty young queens, forty males, and sixty workers.

Criteria of an Animal Society.—As we review the

series of social animals we find every grade between mere gregariousness and well-defined societary forms, and no one can pretend that any hard and fast line can be drawn. There are, however, certain features whose presence, in whole or in part, is diagnostic of a real society. (1) The first of these is the capacity for corporate action. When a herd of herbivores unites against the attack of carnivores when the little cliff-swallows unite in a mob and drive off the falcon, when a band of monkeys nearly tear to pieces the eagle which has swooped upon one of their number, when the wolves hunt in packs, and the pelicans form a living seine-net, wading inwards in a diminishing crescent towards the shore, there is struck beyond doubt the note of society.

Bees will act together to deal with an intruder who has got into the hive, perhaps sealing him up with wax; they will combine to carry away some foreign object; they appear to practise division of labour; they somehow make one another aware of valuable discoveries of nectar.

Yet one must not be too generous. Thus, to take a single example, there may be some truth in the view of Netter that the ventilating bees who make a current by their wings at the entrance to the hive are bees in respiratory difficulties.

Spiders are characteristically individualistic except in their maternal care, but a few social species are known, e.g. *Stegodyphus gregalis* from South Africa, *S. sarasinorum* from Madras, and *Uloborus republicanus* from Venezuela. The Madras form is described by N. S. Jambunathan as forming a sponge-like nest of ramified canals, which is often attached to the branches of trees or to the leaves of the prickly pear. The number in a nest varies from 40 to 100,

males and females usually in the proportion of 7 : 1, though sometimes there are still fewer females. It is said that these spiders sometimes work together, e.g. in securing a victim, and that they share the food without quarrel. There is no marked dimorphism of the sexes, which live together amicably—in a sort of millennium among spiders. The maternal care is very highly developed.

(2) Another diagnostic feature is the existence of division of labour, implying some measure of mutual dependence. The different types in the ant-hill, the termitary, and the bee-hive are the best illustrations, but we see the same 'idea' in the posting of sentinels, which is well known among both birds and mammals—witness, for example, rooks and monkeys.

(3) In some cases we seem to be warranted in speaking of social conventions. Thus in certain species of ants it appears to be the unwritten law that the full must not refuse to feed the hungry, and in a rookery it seems to be an established convention that after a nest has reached a certain stage in its construction it is no longer legitimate to steal sticks from it.

In connexion with the origin of animal societies there is probably a hint to be got from the occurrence of temporary socializations. We get an illustration of this when migrating birds form a company—sometimes relatively small, as when the V-shaped band of wild geese passes 'honk-honking' overhead; sometimes innumerable, as when vast flocks of plover pass southwards in the autumn. Another illustration may be found in the march of the lemmings when they are compelled by over-population and the consequent dearth of food to leave their homes; and it is interesting to notice what audacity and persistence the force of

numbers seems to lend the little rodents on these occasions.

The advantages that animals gain by forming societies are many. They gain a firmer footing in the struggle for existence. There is strength in numbers, as is well illustrated by the ants—a little people, but greatly dreaded. There is strength in co-operation, for several can effect what a single individual need not even attempt. Several ants together will carry a large spider. When there is division of labour and some exchange of services, the advantage grows. Thus it is obviously great gain to have sentinels posted, to have some members at home while others are abroad, to have a leader and a change of leader in the migrating phalanx. Sometimes the economy of the division of labour is startling. Thus Fabre has told us of the mother Halictus bee, who, when she is too exhausted for maternity, becomes the concierge of the establishment, admitting and excluding visitors as her discretion directs.

There appears to be an intellectual advantage in sociality, if we may argue from the fact that many social animals show a high development of wits. The three cleverest kinds of birds are rooks, cranes, and parrots, and they are notably social. There is, of course, a danger of putting the cart before the horse, for it may be that the sociality is in part the expression of good brains. It may also be argued that the non-gregarious crow is just as clever as the social rook, and many analogous instances might be given. On the other hand, beavers belong to the slow-witted order of Rodents, and though the reports of their sagacity have been greatly exaggerated, there is no doubt that they show considerable intellectual ability. The probability is that both points of view are right; the formation of a society implies a certain fineness of intellectual or instinctive

fibre, but the social life improves upon this up to a certain point. Every one knows how much the mind of adult man is a social product.

Another advantage that must mean much is bound to accrue when there is any sort of permanent product which is handed on from generation to generation as a sort of external heritage. The loosely built ant-hill, the hard edifice of the termitary, the honeycomb of the bee, express a sort of communal art and a registration of achievement, and must be of importance in the continuance of the social life. In the more intelligent types there is probably something in the way of social tradition which secures a persistent strategy, as when beavers cut a long canal through an island or gradually build up a very strong dam.

The defensive value of social organization is very well illustrated in the case of many of the ants. In reference to the South European harvesting ants (*Atta structor* and *Atta barbara*) Mr. Moggridge noticed that their enemies treated them with great circumspection. Lizards eat only the winged males and females and try to keep out of the way of the workers, who in their turn do their best to be an effective bodyguard to the winged forms. There is a large proportion of soldiers, some of which are literally walking jaws, always ready to snap and to hold on to the death. Of another enemy, the Tiger-beetles (*Cicindela*), it is said that although they devour the workers, they keep out of the way of the main body and look after the stragglers only. If they fail to catch the ant at the strategic point, just behind the neck, they are said to let go at once, as if they were aware that if the ant's jaws once close on any part of their limbs or feelers they will not leave go again, even after death.

Other Illustrations

In a rookery we have familiar to all an illustration of communal life which is far nearer human society than are the more elaborate instinctive integrates of ant or bee. Rooks are permanently gregarious, feeding together, flying together, and nesting together. There seems no doubt whatever that they post sentinels—a devolution of duty which is in itself social. And there appear to be certain conventions which must be observed, disregard of which is punished.

Hudson gives a delightful picture of the simple social life of the Viscachas, burrowing Rodents of the Pampas. Twenty or thirty burrows are made close together, as in a rabbit warren. The earth is carried off for a short distance and may form a mound on which the Viscachas sit in the evening. After sunset they go a-visiting to the adjoining settlements, and their well-trodden paths show that there is much coming and going. They seem to be stupid little creatures, but it is hard to deny them a love of company. Hudson says he doubts if there is any four-footed creature so loquacious as this little Rodent, or with a dialect so extensive. Sometimes the farmer fills up the burrows and tries to smother the Viscacha villagers, but Hudson relates that when the visitors come at night they try vigorously to dig their entombed neighbours out again. Surely more than a touch of sociality.

Much that is exaggerated has been said in regard to beaver-villages, but there is no doubt that individuals co-operate in relatively gigantic enterprises. It is probable that in previous ages this extremely shy animal lived in larger communities and engaged in even greater endeavours. To make a dam half a mile in length, or to cut a canal

through an island in the middle of a river, are large collective tasks, which are especially interesting because they do not justify themselves greatly, if at all, *until they are finished.*

Domestication

It is very well known that a few species of ants treat certain Aphides or green-flies as if they were domestic animals. They 'milk' them, stroking them with their antennæ, and inducing the exudation of some drops of 'honey-dew.' They stable them underground in the winter and put them out to pasturage again in the early summer. But this well-known case does not stand by itself.

Many years ago Fritz and Hermann Müller described how the larvæ of a Membracid (*Potnia* or *Umbonia*) were used as milk-cattle by a Brazilian stingless bee (*Trigona cagafogo*). The bee in question is somewhat remarkable for its tastes; it is very fond of oily matters and frequents flowers with many glands; it also feeds on carrion and is attracted to rotten cheese. Its popular name of 'spit-fire' alludes to its intensely irritant venom, for although it is stingless, it has well-developed poison-glands.

Approximating to domestication is the extraordinary relationship, described by Viehmeyer, between a species of ant from Manila (*Camponotus quadrisectus*) and a Lepidopterous pupa. The ant makes a well-known hanging earthen nest and the pupæ are found in special cells in the centre. When the nest was broken the furious ants grouped themselves around the pupæ as if to protect them, but closer investigation showed that their anxiety was not disinterested. At the posterior end of the pupa there is a curious chitinous crater, and opening into this a gland which seems

to secrete a sort of honey dew. It looks as if the pupa served as a food purveyor to the ants, but it would be satisfactory to have some observational verification of this. It would also be interesting to know whether the pupa gets any *quid pro quo*, whether the winged insect when it emerges is not possibly in need of some assistance from the ants.

F. Le Cerf describes a remarkable association between a Lycænid caterpillar and a colony of ants of the genus Cremastogaster. The case was discovered by MM. Alluaud and Jeannel on the Kikuyu escarpment. Certain acacias bear numerous nut-like galls, perforated by an orifice about 1 mm. in diameter through which the ants go out and in. The caterpillar is about 10 mm. in length, curiously like a wood-louse or a Chiton, and bearing very peculiar modified hairs. Its mouth-parts suggest a vegetarian diet, and it probably feeds on the acacia leaves which the ants store. It could not possibly get out of the gall, and it must have been reared there by the ants.

Guests and Pets

A great number of cases are now known where small beetles or other insects live in terms of friendly association with ants. One of the most extraordinary cases is that of the cricket genus *Myrmecophila*, some species of which have become guests of ants. Particular guests are wont to be associated with particular hosts; thus *Myrmecophila acervorum* is usually found in the nests of the black ant, *Lasius niger*, and, in suitable localities, of the red ant, *Myrmica rubra*. The reason for the picking and choosing of a host is probably to be found in some adaptation in the relative size of host and guest. The little crickets get shelter and food; they lick their hosts, who give up some

of their food; they plunder the worker-ants returning to the nest with spoils; they steal from the newly-fed larvæ; they insist on having a share when the ants are eating; and, finally, they sometimes demand food from the ants, raising their forelegs in a peculiar fashion. In this movement and in that of the antennæ, there seems to be something like an imitation of the ants' movements, but in other ways their movements are conspicuously different. Why the ants tolerate them, who can tell? It is interesting to note that *M. acervorum* is purely parthenogenetic, and it is probable that some other species are partially so. The eggs of *M. acervorum*, and probably of other species, are laid in the nests of the host, and the fact that they are few in number and large in size with much yolk may perhaps be correlated with the safe and luxurious conditions which the mothers have found as semi-parasites in the ants' nest. In some cases of 'myrmecophily' the hosts get a little in the way of *quid pro quo*, but what return do these little crickets make save an occasional kiss? It is easy to understand the crickets being content, but why the ants tolerate their presence is a mystery. If they thought of it, they could soon kill them off, for ants can combine and they can bite or sting, but they do not think of it. Perhaps we make an artificial problem by using words like 'guest' and 'host', perhaps the truth is that the crickets do not matter much as long as they are not too numerous. Perhaps and perhaps and perhaps.

Ivar Tragardh has described the occurrence of the larvæ of a Tineid moth in the nests of a New Zealand termite, and the story is very quaint. The larvæ depend upon the material of the nest for their food, and they may be seen moving along in file, at regular intervals as if in a procession,

each escorted by a few soldier and worker termites. It appears that the larvæ exude a strong odour which is attractive to the termites. Just as man may have flowers in a room for the sake of their perfume, so the termites have caterpillars. *Chacun à son goût.*

In not a few cases, the fact of association is well established, but its meaning remains obscure. Thus Mr. F. P. Smith has reported the normal occurrence of a spider (*Thyreosthenius biovatus*) in the nests of the wood-ant (*Formica rufa*). The ants tolerate their guest, which they could readily destroy, but what the spider is after remains undiscovered. It is possible that it feeds on other inmates of the ant-hill (the scavengers and pets); it is possible that it eats the 'ants' eggs' on the sly. There are two other so-called 'myrmecophilous spiders' in Britain—on quite a different footing from spiders found casually wandering about on ant hills—but the significance of the association requires to be looked into.

Slave-Making.—If slave-keeping among ants occurred once or twice, one might think it was some strange aberration among the little people, but there are many instances and many stages of the 'institution'.

A fertilized queen of the red ant, *Formica sanguinea*, may fall after her nuptial flight into a nest of black ants, *Formica fusca*, where there is no queen. She is received and fed, and the eggs which she lays are tended. A mixed colony arises, with the reds as masters and the blacks as slaves, the former being more active in external operations and the latter in the discharge of domestic duties. As the blacks do not multiply, the reds make sallies and bring back pupæ from neighbouring nests of blacks. Those that are not eaten grow up to slavery. Sometimes, how-

ever, the slaves gradually decrease in number, and the mixed colony becomes a pure red colony. In this case, therefore, the slave-keeping need not be more than temporary. In fact, Prof. Wheeler has shown that the largest American colonies of *Formica sanguinea* are very often pure.

In the Amazon ants (e.g. *Polyergus rufescens* in Europe and *P. lucidus* in America) the 'institution of slavery' has developed, and there are probably no slaveless colonies. A fertilized queen is accepted by some queenless colony of *Formica fusca* or *F. rufibarbis*; her offspring are tended and become dominant; and the number of slaves is sustained or increased by slave-capturing raids. Forel calculated that a single colony may capture in the course of one summer as many as forty thousand larvæ and pupæ of slaves—who grow up to do everything for their masters, just as if these were their own kith and kin. For the Amazons can do nothing but raid; their mandibles have become sabres quite unsuited for humble toil; they cannot dig, but to beg they are not ashamed. Dr. Louis Dublin, to whose interesting paper on this subject we acknowledge our great indebtedness, writes:—

"It has been most clearly shown by many observers that, if left for as short a period as two or three days without the aid of their slaves they would starve to death, even if surrounded with an abundance of food. Replace the black ants and the scene changes immediately; the Amazons take new courage and are soon fed with the regurgitated food which the slaves are only too eager to offer them."

In a sense, then, the tables have been turned, and the slaves are the masters. The Amazons fight and reproduce,

but the slaves ' determine the character of the nest, plan and conduct migrations, carrying the Amazons from place to place, the latter subject to no impulse of their own. . . . In America this once widely distributed species is on the road to extinction '.

The next stage, as indicated by Dr. Dublin, is that presented by a light red European ant of considerable size, *Strongylognathus testaceus*, and an active well-organized little form, *Tetramorium caespitum*. The large slave-makers have prominent sabre-like mandibles, but they are too delicate to do injury. They are mock soldiers, there are relatively few of them, and there are no workers.

There are males and females amongst them, and so there are among the ' slaves ' as well. It is possible that this kind of mixed community has arisen by an alliance of two distinct colonies, and that the *Tetramorium*-workers somehow fall under the spell of the *Strongylognathus* males and females, who are absolutely dependent upon them.

The final stage of dependence of one species upon another is represented by the European *Anergates* and by two American forms, *Epœcus pergandei* and *Epipheidole inquilina*, in which there are no workers or soldiers, but simply males and females. In *Anergates* the males are wingless and both sexes are degenerate; they depend on the charity of small groups of queenless and aged workers of the *Tetramorium caespitum* species. This state of affairs seems almost incomprehensible, for it must come to an end with the death of the aged slaves. Dr. Dublin suggests that when this occurs a winged female of *Anergates* must seek out another colony of *Tetramorium* to adopt her.

The problem of the origin of the slave-making is very

difficult. Darwin's suggestion was that many ants capture the pupæ of other ants for food, that some of the stored pupæ might be unintentionally reared, that if their presence in the community was not resented but proved useful, the slave-making habit might gain ground. 'If it were more advantageous to this species to capture workers than to procreate them, the habit of collecting pupæ, originally for food, might by natural selection be strengthened and rendered permanent for the very different purpose of raising slaves'.

Dr. Dublin makes a supplementary suggestion, that we must start from the adoption of the newly fertilized queen of the slave-makers by the workers of an impoverished and queenless colony. He refers to Santschi's observations on a Tunisian ant, *Bothriomyrmex*, which temporarily enslaves the workers of a species of *Tapinoma*. The young queen B was taken into the nest T, where aided or unaided she killed the queen T, and proceeded to lay eggs. The workers of T reared the larvæ of B, but as the slaves died off the community became pure B and self-sustaining. If the ranks of the slaves had been recruited by plundering neighbouring colonies, then slave-making might have been established. If therefore we take together the tendency of the young queen to enter an established nest, the tendency some kinds of workers show to welcome a young queen foreign to their race, and the common habit of capturing the pupæ of other species, we have a basis for understanding slave-keeping.

Man and the Web of Life.—We must end this chapter, as we began it, by emphasizing the practical importance of the conception of the web of life. In securing his own welfare and that of his stock Man must keep the

idea of subtle inter-relations continually in view. It is at his peril that he ignores the idea. All interferences with the system of Nature—notably exterminations and new introductions—must be sternly criticized. Even the conservation or favouring of one set of organisms by artificial means may be fraught with danger. We shall give a few instances of how the circles intersect.

The multitudinous economic relations between animals and man have been clearly classified by Sir Ray Lankester in a preface to a British Museum Report on Economic Zoology (1903):—

A. Captured or slaughtered for food and other products, e.g. animals of the chase, food-fishes, whales, pearl-oysters.

B. Bred, or cultivated for food and other products, or for service, e.g. flocks and herds, horses, dogs, poultry, bees, silkworms, leeches.

C. Promoting operations of civilized man, but not by being killed, captured or trained, e.g. scavengers, like vultures; burying beetles; earthworms, flower-pollinating insects.

D. Causing bodily injury, death, disease, e.g. lions, wolves, snakes, stinging insects, germ-carriers like flies, parasitic worms, etc.

E. Injuring man's domestic animals, cultivated plants, or wild forms important to him, e.g. as in *D*, but also injurious insects, pests like voles.

F. Injurious to man's worked-up products of art and industry, such as buildings, furniture, books, clothes, food and stores, e.g., white ants, wood-eating larvæ, clothes' moths, weevils, ship-worms.

G. Beneficial in checking the increase of *D*, *E*, *F*, e.g. certain carnivorous and insectivorous birds, reptiles, and amphibians; some parasitic and predaceous insects.

That the web of inter-relations includes human interests may be illustrated by reference to the rôle of birds in preserving the balance of Nature. All other life depends on plant life; but the great check on plant life is that of insect life—overwhelming in numbers, overmastering in devices, and appalling in voracity; and the great check on insect life is bird life—and, luckily for us, this again is abundant, alert, and well appetized. It is very interesting that the two great classes of successful fliers should be thus, in the wide economics of Nature, pitted against one another, wings against wings, freeman against freeman, Invertebrate against Vertebrate, 'little brain' against 'big brain,' 'instinct' against 'intelligence.' *Practically* this is the most important conflict of classes that the world knows.

There is a biological suggestiveness in the old saying about the dead flies which spoil the ointment of the apothecary, but it was not till quite recently that the important rôle of flies as disease-disseminators was discovered. Perhaps it was at the time of the Spanish-American war that it began to be clearly recognized that the house-fly was a carrier of enteric fever and therefore full of menace. It is now generally recognized that the house-fly can scatter the germs not only of enteric, but of typhoid fever and of cholera, and perhaps of other diseases as well, such as infantile diarrhœa. It is also known to carry the tubercle bacillus. Wherever there is a breeding ground, e.g. about a heap of stable manure, and the possibility of contamination with disease-germs, the house-fly becomes a most serious danger as a disseminator. What is true for Britain is not less true for the United States, as Dr. L. O. Howard has proved up to the hilt.

The carrying is twofold, external and internal. After it has been feeding on highly infective substances, the fly must have many germs about its legs and mouth-parts and body, and it may readily implant these in human food, But its food-canal is also charged with concentrated infective material, which may be dropped on food, on dishes—anywhere. Professor Nuttall remarks that "in potential possibilities the droppings of one fly may, in certain circumstances, weigh in the balance as against buckets of water or of milk'.

Dr. Gordon Hewitt cites some important experiments made by Güssow, who allowed a house-fly (*Musca domestica*), caught in the room of a house, to walk over a culture plate of agar-agar. He obtained thirty colonies comprising six species of bacteria and six colonies comprising four species of fungi. From another, caught in the open, he obtained forty-six colonies comprising eight species of bacteria and seven colonies comprising four species of fungi. "The tracks of a house-fly caught in a household dustbin yielded 116 colonies of bacteria comprising eleven species, and including such species as *Bacillus coli*, *B. lactis acidi*, and *Sarcina ventriculi*, and ten colonies comprising six species of fungi'. A very important fact, proved by Faichne, is that if the maggot stage be developed in infected typhoid material, then the fly has also typhoid bacilli in its alimentary canal.

It might seem to the uninitiated a sad waste of time to inquire into the House Fly's flying capacities. But it is a very important practical question, for the range of flight determines the fly's range of mischief. Dr. Hindle finds that house-flies tend to travel either against or across the wind. This direction may be directly determined by the action of

the wind, or indirectly, owing to the flies being attracted by odours borne by the wind. Fine weather and warmth favour dispersal, and flies travel further in the open country than in towns, probably because the houses offer food and shelter. In thickly housed localities the usual maximum flight is about a quarter of a mile, but in one case a single fly was recovered at a distance of 770 yards (partly over open fen land). When set free in the afternoon, flies do not scatter so well as in the morning. Liberated flies often mount almost vertically to a height of forty-five feet or more. Every detail of this is important because flies are disease-distributors.

Besides carrying the germs of diseases that affect animals, flies may do something in the way of spreading the diseases of plants. Thus L. Mercier has noticed that a common summer fly, *Sciara thomæ*, carries about the spores of the fungus (*Claviceps*) which causes ergot on rye-grass. The spores were abundant in the food-canal of the fly and did not seem to be digested; they also occurred on the setæ of the body. Although it has not been experimentally proved that the flies infect healthy plants with *Claviceps*, there is no doubt that they carry the germs and that they frequent rye-grass.

Not a few insects are subject to fatal attacks of fungoid parasites, and use is now being made of this to further the destruction of injurious pests. By artificially favouring the dissemination of the fungus it has been found possible to cause a useful plague among the insects. Much good has been done in this way in checking the scale insects which attack the limes in Dominica and Montserrat and similar islands. It has been recently suggested that an artificial diffusion of a fungus, *Empusa muscæ*, which is

a specific parasite of house-flies and their relatives, may be useful as a check to the multiplication of these disease-distributors. One cannot help feeling that such measures should be backed up by more evolved cleanliness.

Man has in great measure freed himself from the disgrace of gaol-fever or typhus fever, the germs of which used to be transmitted from man to man by the clothes-louse, and he is in process of conquering other plagues, a step in the conquest being, in every case, an investigation of linkages. Every one knows how the minute animals which cause malaria (Plasmodium) and sleeping-sickness (Trypanosomes) are disseminated respectively by the mosquito (*Anopheles maculipennis*) and the tse-tse fly (*Glossina palpalis*), and the human importance of these four animals is beyond all estimation.

A curious though perhaps unimportant fact concerning a near relative of the Trypanosomes has been recently reported, and may serve to illustrate possible complications. A species of Leptomonas was discovered by Lafont in the latex of *Euphorbia pilulifera* in Mauritius, and this has been confirmed by G. Bouet and E. Roubaud in regard to other Euphorbias. They regard the infection as local and temporary and without obvious pathological effects. There seems little doubt that the plant is infected through the agency of a bug.

That rats have to do with plague was perhaps referred to in the Bible in the account of an epidemic among the Philistines, which they connected apparently with 'the mice that marred the land'. In more recent times, the association of rat-mortality and human-mortality seems to have been often remarked, and regarded as more than a

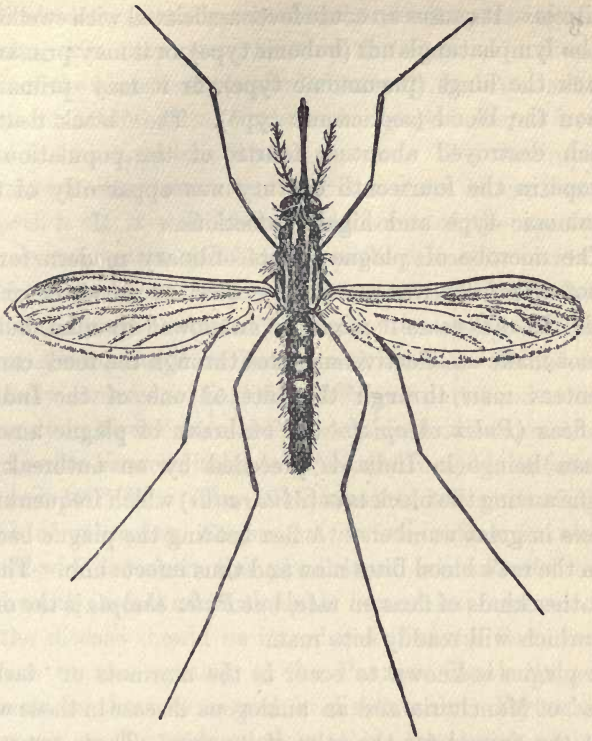


FIG. 57.—A common mosquito, Anopheles maculipennis (female), which carries the Protozoon causing malaria. (*After* Nuttall.)

coincidence. Avicenna refers to it in connexion with a plague in Mesopotamia about A.D. 1000. But the identity of the diseases in rat and man was not established till 1894, when the *Bacillus pestis* was discovered by Yersin and Kitasato. This bacillus is a minute rod-like body with rounded ends, about $\frac{1}{8000}$ of an inch in length. It is fatal not only to man, but to rats, mice, guinea-pigs, rabbits, hares, ferrets, cats, monkeys, and American ground

squirrels. It causes an acute fever associated with swellings of the lymphatic glands (bubonic type), or it may primarily attack the lungs (pneumonic type), or it may primarily poison the blood (septicæmic type). The 'black death' which destroyed about a fourth of the population of Europe in the fourteenth century was apparently of the pneumonic type and highly infectious.

The microbe of plague (in its ordinary modern form) is not *effectively* transported by wind or in water or in food. In rare cases it might be swallowed by man, but it cannot make an effective entrance through the food canal. It enters man through the bite of one of the Indian rat fleas (*Pulex cheopis*). An outbreak of plague among human beings in India is preceded by an outbreak of plague among the black rats (*Mus rattus*) which frequent the houses in great numbers. A flea bearing the plague bacilli from the rat's blood bites man and thus infects him. There are other kinds of fleas on rats, but *Pulex cheopis* is the only one which will readily bite man.

A plague is known to occur in the marmots or 'tarbagans' of Manchuria and an analogous disease in those who hunt the animal for the sake of its skin. There are very large fleas on the marmot, and it is possible that in the epidemics of plague in Manchuria the marmot-flea may play the same part as the rat-flea in India.

There have been many hints lately that mites have a more complicated inter-relation with man and his domestic animals than that which is implied in their being a punishment for lack of cleanliness. (For mites are always trying to clean things up.) It is probable that they have, like ticks, a rôle in the spreading of disease. It has been suggested that the very common follicle-mite (*Demodex*

folliculorum), generally regarded as a trivial parasite of the human skin, may pave the way for some skin diseases. One of the hints we have alluded to is Dr. Dahl's announcement of a new mite, *Tarsonemus hominis*, found by Dr. Saul in two cases in a human tumour. Was it simply a parasite in the tumour, or had it a share in causing the growth? It is well known that some of the species of *Tarsonemus* cause gall-like cell-proliferation in plants.

Yellow fever, or 'yellow Jack' as it used to be called, is a dread disease that used to break out on ships sailing to West Africa, the West Indies, and the like. It has occasionally occurred in English and French ports, and at times severely in New York and Philadelphia, but it is practically confined to between latitude 40° N. and S. and longitude 20° E. and 100° W. The fell disease is transmitted by a kind of mosquito, *Stegomyia fasciata*, which is almost world-wide between the parallels of latitude 40° north and south, a fact of incalculable human importance. For if the disease should be introduced into the East, for instance by the opening of the Panama Canal, *Stegomyia fasciata* is there to spread it disastrously. Fortunately, however, to be forewarned is to be forearmed, and the forearming is now feasible enough. Since the American Commission in 1899 proved up to the hilt what had been previously suggested, that *Stegomyia fasciata* is the carrier of the disease, the prevention of yellow fever has become possible. The mosquito in question is a 'house-haunting' insect, and it always breeds near dwellings. The larvæ develop in artificial collections of stagnant water, for instance in old pots and pans. If these breeding-places are destroyed, if the mosquito nets and screens are used, and if patients are screened and segregated, so that fresh

mosquitos be not infected, then Yellow Jack is conquered. As a matter of fact, the disease has been quite stamped out in Havanna.

It comes to this, then, that the great practical lesson of Natural History is to recognize the complexity of inter-relations, 'the wheels within wheels'. In a report of a lecture by Mr. James Buckland, we read: 'The destruction of the white heron for its scapular plumes has robbed half the world of a bird which is most useful to man. Its loss to India and to China is most serious. It never touches grain, but feeds solely near water and over damp ground, the breeding-places of innumerable batrachians, small crustaceans, and pestiferous insects, all of which directly or indirectly injuriously affect crops in the neighbourhood. The presence of the white heron in the rice-fields, for instance, is distinctly beneficial to the farmer, and rice is one of the most extensively grown crops of India and of China.'

In this connexion it may be useful to point out that many eliminations consequent on Man's intrusion cannot be directly brought home to him as the results of any ruthlessness. Thus one of the most extraordinary of recent disappearances is that of the Passenger Pigeon (*Ectopistes migratorius*) which used to breed, within the memory of living man, in huge numbers in the North American forests. Wilson, the American ornithologist, estimated a flock at 2,230 millions, and in 1912 there was said to be only one individual left, a female bird, about nineteen years old, belonging to the Zoological Society of Cincinnati. It is difficult to believe that there are not survivors in the woods, but persistent efforts to find them have not been rewarded with any success.

A second point of importance is that very strong encouragement has rewarded many of the endeavours to conserve life—endeavours now happily on the increase. Thus the three herds of bison maintained by the Government of the United States comprised in 1910 over 150 head, and the total of pure-bred bisons living in North America was a little over 2,000—a satisfactory result of careful protection. Equally full of promise are the records of reserve-areas and bird-sanctuaries (like those of the Selborne Society in Britain and the Audubon Society in the United States), and of individual efforts (we think, for instance, of Mr. Ford, the well-known motor-car manufacturer) to conserve what may be fairly called vital assets.

In Conclusion.—These few instances must serve to illustrate the fact that animated Nature is a vast system of linkages and inter-relations. No creature lives or dies to itself. The threads of one life get caught up and intertwined with those of another. The liver-fluke of the sheep cannot get on without the water-snail, nor the bitterling without the freshwater mussel, nor the mussel without the minnow, or some such fish, nor the clover without the bee. We find these inter-relations in all degrees of perfection, some old established and working smoothly, others in the making or on trial, and others again apparently making for the extinction of one at least of the associates. But in whatever stage of evolution they are, their interest is great, the web of life is a great fact in Nature, and it is one of the naturalist's delights and tasks to discern the threads.

The general idea we have been expounding was tersely put in an address by Dr. T. Muir. 'The specialist must aim a little more at width of outlook and knowledge of men and affairs, must seek to moderate his exaggerated estimate

of the importance of his own little domain, and must try to see good in the labours of other specialists in fields far distant from his own, never forgetting that all fields are but perfectly fitted portions of a cosmic whole, and that, as the botanist and the astronomer in particular must come to know—

> 'Thou canst not stir a flower,
> Without troubling a star'.

When we think quietly over the extraordinary series of facts brought together in this chapter—which is but one of a possible thousand and one nights of tales—we confess to a feeling of wonder. Life overwhelms us with its subtlety of linkage.

We recognize, of course, that many haunts of life are densely crowded, and commoner rubs elbow with patrician in the throng of the streets, but the wonder is the intimate interlinking of life with life. Contact is nothing, it is the correlation that impresses us. Flowers and their visitors fit one another as glove and hand; cats influence the clover crop and the incidence of the plague in Indian villages; water-wagtails have to do with the success of sheep-farming, and mosquitoes with the decadence of Greece.

This is one of the big facts of life, the correlation of organisms; and, to our thinking, its deep significance is twofold. On the one hand, it seems congruent with the deep-seated tendency of Nature to complexity. It looks as if a story were being told. For there is reason to believe that in the course of time atoms became molecules, and molecules larger molecules, and these colloidal masses. It is conceivable that these incorporated partner molecules and became protoplasm; and that, by and by, viable units of protoplasm, to wit, living creatures, emerged, and a world

of life began. Our hypothesis, based on many facts, is that in this new world of life the complexifying tendency continued, and we call that the self-differentiation of protoplasm. Living creatures traded with time and found fuller and fuller self-expression. No one doubts that many kinds of 'flesh' originated, one kind of fishes, another of birds, another of beasts, another of man, as was said in olden time.

But we must add to this or superimpose on it another idea, that the living creature is associative. We do not wish to multiply formulæ or mysterious tendencies, but there seems to be a touch of protoplasm that makes diverse creatures kin. A quaint instance may serve as a diagram. In recently examining at Roscoff a large collection of the little green worms known as *Convoluta roscoffensis*, Marcel A. Herubel found among them about forty specimens of *Convoluta flavibacillum*, a species which is not green, which had not been previously noticed in this locality. The peculiar fact was observed, that on the ventral surface of each of them there was a young *C. roscoffensis*, clinging on by its dorsal surface. When they were separated in the aquarium, they were re-united in half an hour! The meaning of the peculiar association remains quite obscure, but, whatever it may be, the case may serve to illustrate our idea, that many organisms go about with, as it were, tendrils linking themselves on to other organisms. We have no great faith in the multiplication of 'tropisms', or inherent predispositions of organisms to move on certain ways in answer to precise stimuli, but we would suggest an addition to the list, viz. 'biotropism'—the attraction of organism to organism. To rank this beside 'geotropism', 'heliotropism', 'thigmotropism', 'chemotropism', and

the like will not indeed make occurrences any clearer, but it may serve as a useful labelled string for a large series of facts—the linking of one organism to another, at points where their lines of life intersect, although we often cannot see any obvious reason why they should do so. After the event, we say, 'It pays'; but who could have predicted its success. In any case, the correlation of organisms in the web of life is a large fact. Nature continues to complexify her system.

CHAPTER VI

THE CYCLE OF LIFE

(From Birth through Love to Death)

'Every instant she commences an immense journey, and every instant she has reached her goal'. 'Her life is in her children'. . . . 'Her children are numberless'. . . . 'Her crown is love'. . . . 'Over greatness she spreads her shield'. . . . 'Death is her expert device to get plenty of life'.

—*Goethe's Aphorisms*, translated by Huxley.

The Curve of Life—The Continuance of Life—The Wonder of Development—Growth—Young Animals—Adolescence—Courtship among Animals—Parental Care and the Family—Ageing and Senescence—Death—Illustrations of Life-histories—The Story of Niners.

THE living creature is always changing in its material composition, yet it has a remarkable power of retaining its integrity. This is one of its secrets. It burns, but is not consumed. Besides this, however, it has the power of passing from form to form, from phase to phase—the power of 'cyclical development', as Huxley called it. This is our main theme in this chapter.

The Curve of Life.—From a microscopic egg-cell, hidden within the ovule, fertilized by a pollen-nucleus, an embryo plant develops; the seed is sown and a seedling develops; the seedling becomes a sapling; this grows into a tree which bears flowers and seeds year after year, it

may be for centuries, but finally becomes old, decays and dies, falling to the ground, 'dry, bald and sere'.

Speaking of the beanstalk developing from the bean, Huxley wrote:

'By insensible steps, the plant builds itself up into a large and various fabric of root, stem, leaves, flowers, and fruit, every one moulded within and without in accordance with an extremely complex, but, at the same time, minutely defined pattern. In each of these complicated structures, as in their smallest constituents, there is an immanent energy, which, in harmony with that resident in all the others, incessantly works toward the maintenance of the whole and the efficient performance of the part it has to play in the economy of nature. But no sooner has the edifice, reared with such exact elaboration, attained completeness, than it begins to crumble. By degrees, the plant withers and disappears from view, leaving behind more or few apparently inert and simple bodies, just like the bean from which it sprang; and like it endowed with the potentiality of giving rise to a similar cycle of manifestations'. . . . It is a 'Sisyphæan process, in the course of which the living and growing plant passes from the relative simplicity and latent potentiality of the seed to the full epiphany of a highly differentiated type, thence to fall back to simplicity and potentiality' (*Evolution and Ethics*, 1893).

The life-cycle is even more striking among animals. The fertilized egg-cell divides and redivides; the segmentation-cells are arranged and differentiated; an embryo is formed, which goes on developing, directly or circuitously, until the result is a reproduction of the parent organism. But when the ascent from a *vita minima* at the start has reached the *vita maxima* of maturity, there begins to be a

reversal of the process. There is a quick or slow descent to the *vita minima* of senescence, ending in natural death, if violent death has not previously intervened. Varied as the life-histories are, there is always the same general phenomenon of cyclical development.

The shape of the curve differs greatly in different types. Some have a short youth, *e.g.* Aphides, which are almost like adults at birth and set to work at once; while others have a long youth, *e.g.* frogs, which spend about three months in the larval state. Some have a prolonged maturity, *e.g.* most birds and mammals; while others have it soon cut short, *e.g.* May-flies, which are sometimes literally insects of a day. There may be prolonged adolescence, as in an eel, or a precocious maturity, as in a rat. Two general ideas should be borne in mind (*a*) that life-histories differ from one another in the lengthening out or shortening down (sometimes even telescoping) of particular periods; and (*b*) that they differ much more intimately in the details of the curve—in the minor ups and downs—which mark the vicissitudes of days and seasons, and the often correlated internal periodicities.

The Continuance of Life.—A chronometer well-wound can keep agoing for a long time, but it eventually comes to a standstill, and so does the organism. An intricate device like the famous Strassburg clock may go through a complicated performance, with processions of figures and the like, but eventually the mechanism runs down and the show is over. So is it with the organism. But there are several big differences between an organism and a mechanism, and one is that the organism normally gives origin to other organisms like itself or shares in so doing. It multiplies or reproduces itself.

Thus the life of the organism is very different from the path of a rocket in the air, which spends itself wholly in its brilliant career, for normally the organism has offspring. The vital trajectory is different from the course of the drops of water in a fountain, which rise to the summit, sparkle a moment in the sunlight, and sink again to earth. The organism secures the continuance of its kind.

The Wonder of Development.—There are some beautifully transparent eggs which we can watch as they develop, actually witnessing the divisions and displacements of cells. The egg of one of the moths, *Botys hiemalis*, is a good illustration, and there are few processes that go on in the world more impressive than this development—the emergence of the obviously complex from the apparently simple. In the case of the hen's egg, that we are so familiar with, a small drop of transparent living matter lies like an inverted watch-glass on the top of the ball of yolk. From that drop, in the course of three weeks, the chick is built up—the most familiar fact in the world and surely wonderful. In his forty-ninth Exercitation on 'the efficient cause of the chicken,' Harvey quaintly expressed his sense of the wonder :—

'Although it be a known thing subscribed by all, that the fœtus assumes its original and birth from the male and female, and consequently that the egge is produced by the cock and henne, and the chicken out of the egge, yet neither the school of physicians nor Aristotle's discerning brain have disclosed the manner how the cock and its seed doth mint and coine the chicken out of the egge.'

Development is the 'becoming' of the individual organism. It is the attainment of a specific form and

structure, and of the not less characteristic associated faculties or activities. Often we cannot tell one kind of egg from another, but the one will develop into a starfish and the other into a sea-urchin, one will become a reptile and the other a bird. Development is the expression or realization of an inheritance.

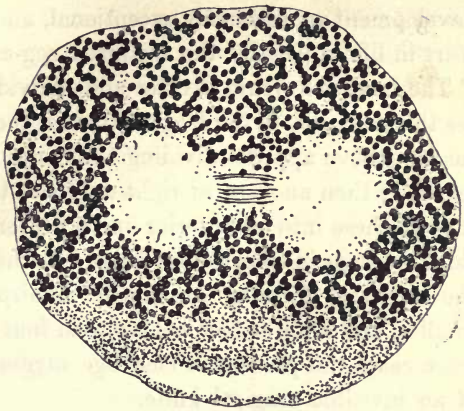


FIG. 58.—Egg of Ascidian, Ciona intestinalis, *after* Duesberg, to show distribution of organ-forming substances in the egg, which is about to divide into two. At the lower pole there is a distinct crescent with very crowded small granules (plastochondria); around the division-spindle in the centre there is a clear zone; the upper portion of the egg has numerous yolk granules and few plastochondria.

The starting-point of an individual life is usually a fertilized egg-cell—a new unity formed by the intimate and orderly union of paternal and maternal inheritances, conveyed we know not how in the often microscopic egg-cell and the extremely microscopic sperm-cell. There may be development from a bud or from a fragment of a parent organism—this is the expensive process of asexual reproduction. There are also many cases of parthenogenesis, where the egg-cell develops without being fertilized. Thus a drone-bee has a mother but no father, but these modes of asexual reproduction and parthenogenetic

development are relatively exceptional, and the individual's start in life is usually the fertilized egg-cell.

The fertilized ovum divides and redivides, and we may see this going on in the frog's spawn in the ditch. In that case a groove appears dividing the ovum into a right and left cell; then another, at right angles to the first, dividing each of these into an anterior and a posterior half; then a third cleavage in a horizontal plane cuts the four cells across the equator, forming an upper hemisphere with four smaller, and a lower hemisphere with four larger cells. In some cases the process of cleavage suggests the operation of an invisible magical knife.

For a time the process of division continues without there being any growth, and a ball of cells (or blastomeres) is formed which is still no larger than the original unsegmented ovum. But growth soon begins, and the cells are arranged in germinal layers, or are variously localized by processes of infolding and overlap. Sooner or later the cells begin to show differentiation, some laying the foundations of the nervous system, others of the muscular system, others of the digestive system, and so on. And besides differentiation there is the process of integration —the unification and co-ordination of the developing organism. In short, there is a process of embryonic development—condensing into a few days or weeks the achievements of ages of evolution.

At a certain stage, differing greatly in the different types, the egg is 'hatched', and there emerges from the egg-envelope—a young creature which is a delightful miniature of the adult, as in the familiar case of a chick, or a larva very different from the adult, as in the case of caterpillar and tadpole. The embryo is the quiescent stage within

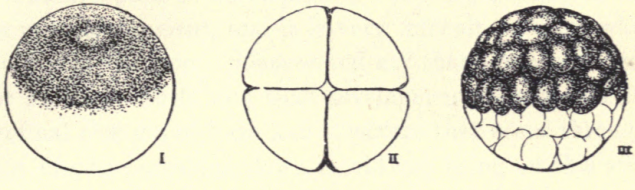
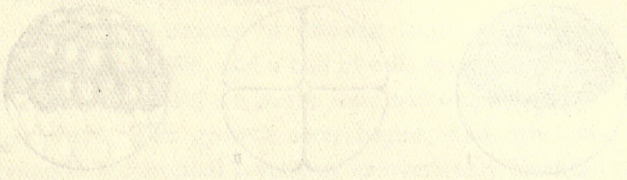


FIG. 58A.—Segmentation of the egg of African Clawed Toad, Xenopus lævis. I. The unfertilized egg with pigment and the nucleus in its upper hemisphere. II. The 8-cell stage, seen from below. III. The early blastula or 'ball of cells' stage. (*After* E. J. Bles.)



the egg-membrane; the larva is free-living and able to feed for itself; but the larval stage may be suppressed, and then we say that out of the egg-envelope there emerges a young creature. Thus in one type the embryonic development is succeeded by a long larval period, while in another type the embryonic development eventuates in a young creature like a miniature of the parent.

It is very difficult to discover a quite satisfactory punctuation of life—to say for instance when development stops. As long as the expression of the inheritance goes on, as long as differentiation and integration continue, we may certainly speak of development, but mere increase in size is not development, and it is very difficult to know when to put in the stop. Some would say that there is no stop at all until death, and that development includes all the normal changes of form and structure that occur throughout life, the breaking down in old age being on this view just as much part of development as the building-up of youth. This usage seems more logical than useful, for the changes of senescence are for the most part of the nature of 'involution' rather than of evolution.

Others would put in the stop when the limit of growth is reached, but the brain may go on developing long after that, though in mammals there seems to be no increase in the actual number of brain-cells after birth. Moreover, as we have seen, there are many fishes and reptiles that show no limit of growth.

Others would put in the stop when the specific characters are well-defined, when the creature has put on the dress that is its own and no other's. There seems a great deal to be said for this punctuation, but it is open to the objection of excluding much that can be justly called develop-

ment, *e.g.* the changes associated with sexual maturity. The fact is that, in studying development, we are considering the living creature in its time-relations, and definition is a matter of convenience.

The first wonder of development is the minuteness of the starting-point. Even when we use the comfortable word potentiality, we find it difficult to deny the wonder of condensing a complex inheritance into a microscopic germ-cell. An ovum the size of a pin's head is a large ovum, as ova go. Many are microscopic, and a spermatozoon may be only $\frac{1}{100,000}$th of the ovum's size. Can there be room in these minute vehicles for the complexity of organization which an inheritance implies ?

The wonder grows when we consider some of the facts of modern embryological research. Prof. Delage cut the very minute egg of a sea-urchin into three parts, and reared a larva from each of them. In another case he reared an embryo from $\frac{1}{37}$th of a sea-urchin's egg. Twin animals may often be obtained from one ovum by producing a separation of the first two cleavage-cells. Professor E. B. Wilson produced quadruplets by shaking apart the four-cell stage in the development of the lancelet.

The second wonder is germinal continuity. These germ-cells are not ordinary cells ; they are like the fertilized ovum which gave rise to the parent. All the cells of the body are continuous with the original fertilized ovum by a succession of cell-divisions, but in the case of the germ-cells the lineage is undifferentiated. In many cases, scattered throughout the animal kingdom, from worms to fishes, the beginning of the lineage of germ-cells is demonstrable very early, before the division of labour implied in building up the body has more than begun. Even when this early

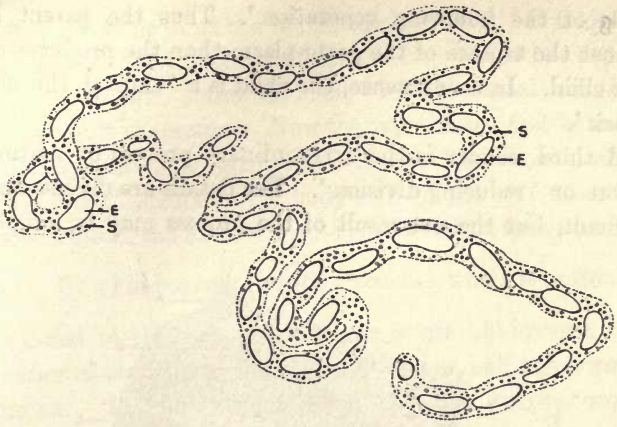


FIG. 59.—Chain of embryos (E,) of Encyrtus fuscicollis, all arising from one ovum, bound together by a chain of mucus (S.) *After* Marchal.

segregation of the germ-cells is not demonstrable, we know that the germ-cells do not arise from differentiated body-cells. They are cells which retain intact the qualities of the fertilized ovum which gave rise to the parent. Similar material to start with, similar conditions in which to develop—*therefore*, like tends to beget like. Two famous quotations may make this fundamental fact of germinal continuity quite clear. There is a sense, Galton said, in which the child is as old as the parent, for when the parent's body is developing from the fertilized ovum, a residue of unaltered germinal material is kept apart to form the reproductive cells, one of which may become the starting-point of a child. To use Weismann's words : ' In development a part of the germ-plasm (*i.e.*, the essential germinal material) contained in the parent egg-cell is not used up in the construction of the body of the offspring, but is reserved unchanged for the formation of the germ-

cells of the following generation'. Thus the parent is rather the trustee of the germ-plasm than the producer of the child. In a new sense, the child is a 'chip of the old block'.

A third wonder is the extraordinary process of maturation or 'reducing division'. The details are diverse and difficult, but the net result of the process may be simply

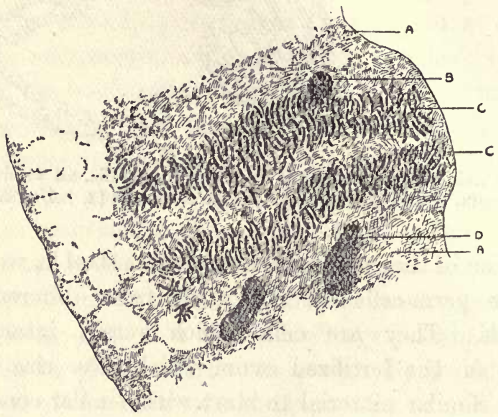


FIG. 60.—Part of a dividing cell, a Radiolarian, showing the chromosomes in two groups. A, the cytoplasm; C, the chromosomes; B,D, differentiations in the cytoplasm. (*After* Haecker.)

stated. In each cell in the body of an organism there is normally a nucleus or kernel, and within the nucleus a definite number of readily stainable rods, or loops, or granules, called chromosomes. Each kind of living creature has a particular number, thus there are twenty-four in man, mouse, and lily; sixteen in ox, guinea-pig, and onion; twelve in the grasshopper; two in one of the threadworms, and so on. There is no doubt that these chromosomes are very important, and most biologists regard them as the

bearers or vehicles of the hereditary qualities. It is quite safe to say that the chromosomes, along with other germ-cell constituents, stand in some definite causal relation to the adult characters. Now the remarkable fact is that, while the quite immature germ-cells have the same number (n) of chromosomes as the body-cells of the species under consideration, the mature germ-cells have half that number $\left(\frac{n}{2}\right)$. By a kind of cell-division (*meiosis*), which is normally restricted to this one point in the entire life-history, the number of chromosomes is reduced to one half the normal number. It follows that when the ripe spermatozoon and the ripe ovum—each with $\frac{n}{2}$ chromosomes—unite in fertilization, the normal number n is restored. If there were not some reduction of this sort, the number of chromosomes would be doubled at each fertilization, which is absurd. Moreover, in the reduction, which, in the case of the egg, means the absolute rejection of half of the chromosomes (which are usually carried off by the first ' polar body ' and come to nothing), we see an opportunity for permutations and combinations among the items of the inheritance, *e.g.* for the dropping out of a character altogether. If we compare the inheritance so far as it is borne by the chromosomes to a pack of cards, there is a remarkable throwing away of half of the pack and their replacement by half of another pack at the beginning of each individual life.

The fourth wonder is fertilization—the intimate and orderly union of the reduced nuclei of the two sex-cells. There are several processes involved which may be analysed apart. There is the mingling of two inheritances,

which usually come from two different parents, and it is important to understand that the spermatozoon from the one parent and the ovum from the other contribute the same number of chromosomes, except in certain very interesting cases where half the spermatozoa have an extra chromosome. Furthermore, anticipating a little, we may notice the ocular demonstration of the fact that when the fertilized ovum divides, each daughter-cell or blastomere receives the normal number of chromosomes, half of which are of maternal and half of paternal origin. This has been followed for several divisions, so that, if the chromosomes are (even in some measure) inheritance-bearers we have a remarkable confirmation of the truth of the prophetic statement which Huxley made in 1878:

'It is conceivable, and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web of which the warp is derived from the female and the woof from the male'.

In the animal kingdom it is usual for cells to have in their cytoplasm, outside their nucleus, a minute body known as the centrosome, which becomes two when the cell is going to divide, and seems to play an important part in the process of division. In the animal ovum the centrosome disappears, and it is part of the process of fertilization that the spermatozoon introduces a centrosome. This divides into two, and these have their rôle when the egg divides. One passes into each daughter-cell or blastomere.

Another aspect of fertilization is that the entrance of the spermatozoon, or the reproductive nucleus of the pollen-grain in the case of the flowering plant, does in some way

stimulate the ovum to divide, or remove some embargo which hinders the ovum from starting on its course of development. It is possible that some ferment may be introduced in ordinary fertilization, but the remarkable experimental work of recent years shows that a great variety of stimuli may serve to set the egg dividing. It is difficult to discern what is the common feature in these diverse trigger-pulling stimuli.

Artificial Parthenogenesis.—Our knowledge of the very interesting phenomena commonly referred to as artificial parthenogenesis is in great part due to two experimenters of the first rank, Professor Jacques Loeb and Professor Yves Delage. Loeb began by showing that the action of the male element could be facilitated or its range of possible action increased by altering the conditions. In sea-water rendered faintly alkaline the eggs of the sea-urchin could be fertilized by the sperms of many different kinds of starfish, though this did not occur in ordinary sea-water. But this was but the beginning of his remarkable series of researches. He put the eggs of the sea-urchin into sea-water to which had been added a little formic, acetic, or butyric acid, and then after a minute or two replaced them in normal sea-water. They began to show the initial stages of nuclear division. But when he transferred ova from the acidified sea-water to more concentrated sea-water, to which common salt had been added, they developed normally and at the usual rate, and formed free-swimming larvæ. Similar experiments have been successfully made with several kinds of worms and molluscs.

Loeb, Delage, and others have shown in a considerable variety of cases that artificial parthenogenesis can be

induced by many different kinds of stimulus. To set the egg dividing a mechanical stimulus such as gentle brushing or a pin-prick may suffice ; or a slight disturbance of the chemical composition of the sea-water may serve ; or some alteration of the osmotic conditions by adding something to the water ; or exposure of the eggs to certain vapours or to electric discharges. The puzzling feature is the diversity of effective stimulus. In many cases the artificially stimulated egg divides and re-divides, but eventually comes to naught. In a few cases, viable young animals develop. Thus Professor Delage reared a miniature sea-urchin from an unfertilized ovum, and Fritz Levy reared young frogs.

Without attempting any survey of the very striking series of experiments, we may refer to two or three which are particularly instructive. Winkler made an extract of sea-urchin spermatozoa and put some of it in water containing sea-urchin eggs. The eggs developed, and it was inferred that the extract had ' fertilized ' the eggs. The observation was right, the inference was wrong. For Gies and Pichon showed that Winkler's results were due to osmotic influence. The same results can be obtained by using reagents that have nothing to do with sperm-extract. Kupelwieser made the very interesting experiment of bringing the spermatozoa of the mussel (*Mytilus*) into contact with eggs of sea-urchins (*Strongylocentrotus* and *Echinus*), with the result that the eggs developed into larvæ. Microscopic analysis showed that the chromosomes of the mussel spermatozoon played no part in the fertilization, but that the centrosome introduced by the spermatozoon took part in the cleavage process. The larvæ showed only maternal characters.

Very striking experiments have been made by M. Bataillon on frogs' eggs, and confirmed by M. Henneguy. Under proper precautions the eggs were taken from a frog, placed in a flat dish, pricked with a needle of platinum or glass, and then covered with a layer of water which had been sterilized by heat. In about four hours the eggs began to segment, and about a fifth of them did it normally. Out of a thousand eggs, a hundred and twenty hatched into tadpoles, and one of these lived till it was about three months old and almost a perfect frog. As it has been remarked, 'in the hands of these physiologists, the little needle was as potent (or almost as potent) as Aaron's rod'.

In one of his experiments, Bataillon took a piece of a string of toad's spawn with as little jelly as possible, put it in a dry dish, bathed it with a little blood, and made little punctures in the eggs. They segmented 'magnificently', and the frog's blood works as well as the toad's, and better than the spermatozoa of the frog! According to Bataillon, pricking the eggs, or exposing them to vapour of chloroform, or subjecting them to electric discharges, and the like, may be sufficient to activate the eggs and induce some cleavage. But if embryos and larvæ are to be developed, there must be something more; there must be an introduction of some organic, apparently nuclear, matter, which probably exerts a catalytic influence. Thus frogs' eggs moistened with blood and then pricked will develop into larvæ. The pin-prick plus the introduced blood corpuscle take the place of the spermatozoon in normal fertilization.

Fritz Levy followed the method of pricking the frogs' eggs with a platinum needle, which was sometimes first dipped in salt or in the blood of the mother. He repeatedly

reared tadpoles by this aspermic development, and he was thrice successful in reaching the stage of miniature frogs. It is interesting to find that the nuclei were smaller than the normal, and Levy believes that they had only half the normal number of chromosomes.

The experiments in question illustrate very clearly that, as we have indicated, several quite distinct things take place in ordinary fertilization. The entrance of the spermatozoon implies some degree of mingling of the paternal with the maternal inheritance, and it also implies some stimulus to cleavage or the removal of some hindrance. In the artificial parthenogenesis effected by MM. Bataillon and Henneguy the rôle of sperm-stimulus was discharged by a needle, and the inheritance remained, of course, purely maternal, for there cannot be a hybrid between a needle and a frog. As a French writer puts it: 'il ne peut être question d'hérédité du côté du père, car on ne voit pas très bien les jeunes grenouilles héritant des propriétés de leur épingle paternelle'. While some incline to think that the spermatozoon introduces a stimulus, perhaps of the nature of a ferment, Loeb has suggested that the spermatozoon may remove 'a negative catalyser or condition', the presence of which somehow keeps the ovum from developing. The stimulus may be the removal of an inhibitory influence. Further experiments are required before this question can be securely answered.

We have seen that a quite ripe ovum has in its nucleus half the normal number of chromosomes; if this ovum be artificially stimulated to development, the cells of the young animal should also contain only half the normal number. According to Dehorne, this was the case in an eight days' old frog-tadpole, reared from an

unfertilized egg; the cells of the body had only half the normal number of chromosomes. In some cases the number seems to be normal, which may be due to the fact that the ova began to develop under artificial stimulus before the ordinary reduction process had occurred; or to a subsequent restoration of the reduced number 'by a process of auto-regulation', as is said to be the case in Delage's parthenogenetic sea-urchin larvæ.

The general opinion of experts is thus summed up by Professor E. B. Wilson. As the ovum is much the larger, it is believed to furnish the initial capital —including in some cases a legacy of food-yolk—for the early development of the embryo. From both parents alike comes the inherited organization which has its seat (in part at least) in the readily stainable chromatin rods or chromosomes of the nucleus. From the father comes a little body, the centrosome, which organizes the machinery of division by which the egg splits up, and distributes the dual inheritance equally between the daughter-cells. Besides bearing the paternal inheritance, restoring the number of chromosomes to the normal, introducing the centrosome (which serves as 'the weaver of the loom'), and acting as the normal trigger-puller which sets the egg a-going on the path-

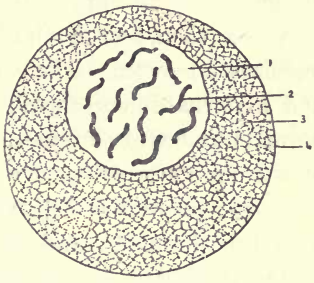


FIG. 61.—Diagram of a cell, 1, the nucleus; 2, the chromosomes, or readily stainable bodies in the nucleus; 3, the cell substance or cytoplasm showing a reticular structure; 4, the cell-wall.

way of development, the spermatozoon may do yet another thing. In some insects and other types, half of the spermatozoa have the same number of chromosomes as the ripe egg $\left(\frac{n}{2}\right)$, while half of them have one fewer $\left(\frac{n}{2}-1\right)$, and there seems to be good evidence that when two equal numbers come together $\left(\frac{n}{2}+\frac{n}{2}\right)$ the result is a female, while an ovum fertilized by a spermatozoon with $\frac{n}{2}-1$ chromosomes develops into a male.

We see, then, how much is involved when a spermatozoon fertilizes an ovum. There is a mingling of the paternal and maternal inheritances; there is a restoration of the normal number of chromosomes; there is the introduction of the minute centrosome which plays an important rôle in cleavage; there is an activation of the egg and a stimulus to embryo-forming; and there is a rapid change effected in the periphery of the ovum, so that it becomes non-receptive to other spermatozoa.

A glimpse into the subtleties that lie beyond may perhaps be given by taking a particular item of fact. Günther Hertwig finds that the eggs of the Edible Frog (*Rana esculenta*) and the Common Toad (*Bufo vulgaris*) may be fertilized by sperms of the Brown Frog (*Rana fusca*). They segment normally, but they die before they reach the gastrula stage of development. But if the spermatozoa of *Rana fusca* be first exposed to intense Radium rays, and then used for fertilization, the eggs develop into larvæ which survive for several weeks. The explanation suggested of this curious paradox may be wrong, but it is illustrative. It is this, that the spermatozoa of *R. fusca*

contain some nuclear element which is not in harmony with the particular protoplasmic composition of the eggs of the Edible Frog and the Common Toad. But if this disharmonious element be destroyed by the Radium influence, the spermatozoon may act as a stimulus to development—which is, in a sense, parthenogenetic. In various organs, it was noted that the surface or volume of the nuclei was half the normal.

Another side-light may be illuminating. In many cases it is possible to effect artificial hybridisation, even between types which are very far apart. A very striking instance is that effected by Professor E. W. MacBride between the eggs of the common heart-urchin (*Echinocardium cordatum*) and the sperms of the common regular sea-urchin (*Echinus esculentus*). The hybrid larvæ, which showed both paternal and maternal characters, lived for only eight or nine days, but all Echinoderm larvæ are delicate and difficult to rear. The interest of the case is that the two parent genera are so far apart. Professor MacBride points out that *Echinus* and *Echinocardium* have been distinct since the beginning of the Secondary epoch, and that their common ancestor could not have lived later than a period which a moderate estimate would place at twenty million years ago ; yet the germ-cells of the two types will commingle so as to produce a hybrid in which both paternal and maternal characters are represented.

No one can dream of dealing in a facile way with development, which is one of the central mysteries of life, but we wish to try to state two general ideas. The first is that development is an active process of self-expression. This may be illustrated by reference to a very important event in development, namely, the out-

growth of nerve-fibres and the establishment of specific nervous connections on which the effectiveness of subsequent activity depends. In 1890 Ramon y Cajal discovered at the end of the embryonic nerve fibres, at a very early stage in their development, what he called a cone of growth, which he compared to the finger-like outgrowth or pseudopodium which the Amœba protrudes when it is gliding over the mud of the pond.

In very vivid words he wrote (1899):

'From the functional point of view, the cone of growth may be regarded as a sort of club or battering ram, endowed with exquisite chemical sensitiveness, with rapid amœboid movements, and with a certain impulsive force, thanks to which it is able to press forward and overcome obstacles met in its way, forcing cellular interstices until it arrives at its destination'.

This was in great part a prophetic interpretation, and many have vigorously opposed the conclusion that the development of nerve paths is really due to the protoplasmic movement on the part of the nerve-cells. But brilliant confirmation of Ramon y Cajal's view has been recently afforded by Professor Ross Granville Harrison, to whose work we wish briefly to refer.

Harrison's experiments show that two elementary phenomena are involved in nerve development: (*a*) the formation of the primitive nerve fibre by an outflowing movement of the protoplasm of a nerve-cell, and (*b*) the formation of neurofibrils within this filament—a process of tissue differentiation.

'It is through the former that the specific nerve paths of the body are first laid down'. 'The energy of outgrowth

is immanent in the nerve-cell, and the initial direction of outgrowth is already determined within the cell before the outgrowth actually begins. The formation of the fibre is therefore an act of self-differentiation within Roux's definition'.

The second general impression that we get from the study of development is that of a continuous action and reaction between an implicit organization and the environing conditions. We include in the environing conditions not only the external medium and its energies, and the maternal environment where such exists, but also the intra-embryonic environment, the influence of surrounding cells and of the whole on any particular developing unit or area. The developing organism is continually trafficking with its environment, and the result is a function of the intrinsic hereditary nature, on the one hand, and of the appropriate environmental nurture, on the other.

In thinking of such a difficult problem as embryonic development, it is always profitable to look at it in the light of the development of which we are most immediately aware—the development of our own mind and character. Of a truth they are both born and made. Our mind is in great part a social product; our character has to be wrought out in conduct. What we are aware of is 'the expliciting of the implicit', the actualizing of something potential, action and reaction between our hereditary nature and a complex environing nurture. Reading back, we feel sure that the same general idea applies to embryonic development. The general idea is that of the seed which will not germinate except in suitable soil, and duly favoured with sunshine and rain; but we wish to push the idea back till we see in each cell of the embryo, in each 'organ-forming

substance ' or plastosome, a seed to which the surrounding cells supply the appropriate environment and the necessary liberating stimuli. Above all, we must not think of the matter too simply, too mechanically. That mechanical factors operate directly on the developing embryo will be admitted by all. There are bound to be pressures and tensions and the like, which make themselves felt. But it has to be borne in mind that the essential process is the active expression of an inconceivably intricate organization, which has been gradually wrought out through tens of thousands of years. When Professor His maintained that the large eyes of the young chick are the direct cause, by compression, of the sharp beak of the bird, he was taking too simple a view of the problem, and mistaking the cart for the horse.

To take a concrete illustration of the absolutely essential influence of the environment. It is well known that the absence of the appropriate temperature at a critical period may have a profound effect. It may arrest cell-divisions in one part of the embryo more than in another, and strange aberrations may result. Or it may operate by hindering the operation of certain ferments. Thus Dr. J. Dewitz placed the nests of a wasp (*Polistes*) in a refrigerator for forty-eight hours, and found that this had the effect of hindering the development of the wings in the pupæ. Similar experiments with the pupæ of the blow-fly (*Calliphora*) also resulted in defective wings. Again we are made to feel that each stage in development has its appropriate external nurture.

Environment affords or denies stimulus, and according to the liberality or parsimony will be, in many cases, the degree of development attained by the animal. A diagram-

matic illustration may be found in the story of Neptune's Cup. This huge cup-like sponge (*Poterion neptuni* or *Cliona patera*) may grow to an immense size—a cup that only a god could drain. It may be a couple of feet in height. Now Vosmaer discovered what Topsent has confirmed, that this huge cup is *the free form* of a small boring sponge which is found making gimlet-like holes in shells. There are also free and prisoner forms of the common *Cliona celata.*

Growth.—The power of growth is one of the insignia of life. It is characteristic of all living creatures, and every one knows in a practical way what it means, though a precise definition is not easy. One may say that growth is increase in the size or volume of an organism, and usually implies increase in mass or weight. But there is evidently no small difference between an increase of size due to a subcutaneous deposit of fat, such as we see in prize pigs and prize fat cattle, and the slow continuous growth of a lean fish like a haddock. There is a marked difference between an enlargement due to the accumulation of watery fluid and the fine growth of an embryo's brain. It is not growth that we see when a parched turnip or the like is surrounded with water and expands, or when a frog, leaving its winter-quarters in the mud, plunges into the pond, and, absorbing water through its skin, may be watched ' swelling visibly '. It seems, indeed, that more than one word is required to cover the various phenomena which may be quite reasonably referred to as *growth.*

We cannot speak of growth as one of the characteristics of living organisms without remembering that the power of growth under suitable conditions is also the fundamental property of crystals. Since Professor Lehmann published

his important work on *Fluid Crystals* in 1904, the conception of crystals has had to be profoundly altered. For he introduced us to what he called the ' new world ' of crystals that are mobile and liquid, yet not separable by any break from those that are rigid and solid. The fundamental character is the power of growing, and Professor Lehmann thinks that this may be, as it were, *utilized* in the growth of organisms. He figures the beautiful growths of purely inorganic ' silicate-vegetation '. But what must be definitely borne in mind is that the crystal can only grow larger *at the expense of material the same as itself.*

Organic growth is essentially a regulated increase in the amount of living matter (protoplasm) and intimately associated substances. It is much more than accretion, it is an active process of self-increase. Unlike a crystal's growth, it comes about at the expense of materials different from the growing substance—often very different, as in the case of plants, which feed on air, water, and salts. Unlike mere expansion, it is regulated in relation to the organism, or organ, or cell that is growing. In all multicellular organisms growth is associated with cell-division, for when the individual cell reaches its limit of growth it divides into two.

As to the *conditions of growth*, the first is Nutrition. Living involves continual wear and tear and not less continual recuperation; growth depends on there being a surplus in the process of self-renewal. In other words, it is a fundamental condition of growth that income should be greater than outlay. Thus the enormous bulk of many plants—like the Big Trees of California—is in part dependent on the fundamental fact that the income of the plant is always high above its expenditure. Animal giants

are rare, and *one* of the reasons for this is that animals live much more nearly up to their income than plants do. It sometimes happens, one must admit, that an organism grows larger for a time without taking in any food—we can see that in the growth of salmon-fry before they begin to eat—but what happens in such cases is a change of condensed stored substances into more dilute and bulkier form. The embryo is cashing and re-investing its legacy of yolk. The same is true of the shoots of a potato, sprouting in a dark cellar; they show true growth though the organism as a whole is actually losing water in transpiration, and, as its respiration shows, breaking down carbon-compounds. What was stored in the tuber is being transformed.

More difficult, perhaps, is the case of a young tadpole, for careful measurements and weighings show that during the period of most rapid growth, the weight of dry substance does not increase at all. During this period, it seems, the imbibition of water is more important than the assimilation of food-material.

Plenty of assimilated food is the *sine qua non* of growth, but the conditions imply appropriate environment along other lines. Growth, like development, has its optimum environment, but this differs so much for different organisms, that it is difficult to make general statements in regard to the agencies that favour and those that hinder growing. What is one organism's meat is another organism's poison. In a general way, it might be said, light is essential for the growth of plants, for the assimilatory process of building up carbon compounds is a *photo-synthesis* dependent on the sunlight. But when we look into the matter more carefully we find that, other things being equal, plants grow more rapidly during the night than during the day.

The strongly refractive, so-called chemical rays, which have little or no effect on assimilation, have an inhibiting effect on growth. The growth of plants is also dependent on humidity, the amount of oxygen, temperature, electrical conditions, and other influences. The optimum temperature usually lies between 22° and 37° C., and there is a complete cessation of growth in plants at a temperature less than 0° C. or higher than 40°–50° C.

For animals the general statement may be made that lowering the temperature puts a brake on growth. It does so, in part, by retarding the process of cell-division, and it does this, in part, by retarding the up-building of nuclein compounds in the cells. Growth is much slower in polar than in tropical seas, and the life-span is more drawn out. For a developing chick, the temperature above which death occurs is 43° C., the minimum at which growth stops is about 28° C., the normal limits are between 35° and 39° C.

Some light on the difficult question of the limit of growth may be obtained from a simple consideration in regard to cell-growth, which seems to have been made independently by Herbert Spencer, Rudolf Leuckart, and Alexander James. Cells may be defined as unit areas or corpuscles of living matter, and, as we have already noted, the growth of multicellular organisms depends on the growth and division of the component cells. A cell may grow by taking up water, and by accumulation of the by-products of metabolism, but essentially by having a surplus in the continual recuperation of the living matter. Now, if we start with a spherical cell and suppose it to grow until it has quadrupled its original volume, it has by no means quadrupled its surface, for the volume increases as the cube of the radius, and the surface only as the square.

But as it is through its surface that the cell is fed, aerated, and purified, functional difficulties are bound to set in as the increase of surface lags behind the increase of volume. There is four times as much material to be kept alive, but there is not four times the surface by which to effect this. A free-living cell, like an Amœba, evades the functional dilemma by flowing out into irregular processes, which greatly increase the surface, making the cell like a country with a much-indented coast-line. But what ordinarily happens is that when the cell has reached its limit of growth, the maximum safe size, it divides into two, halving its volume and gaining new surface. As a general rationale, applicable *mutatis mutandis* to organs and organisms as well as to cells, the suggestion thus briefly outlined certainly helps towards an understanding of the limit of growth. Another important suggestion has been advanced by Boveri and Richard Hertwig, that the limit of growth is in part determined by the ratio of the amount of nuclear material to the amount of cell-substance or cytoplasm.

When an animal grows larger this usually means that its cells are multiplying, but it has been suggested (by Plenk) that in lower animals of small size, such as Rotifers and some Nematodes, an increase in the dimensions of the cells plays an important part in growth. In the cells of some animals with small eggs, such as lampreys and salamanders, there is some increase in the size of the elements, and the same is true of very large cells in higher animals, and of permanent elements like ganglion-cells, muscle-cells, and lens-fibres, which lose their power of division at a very early stage. On the whole, however, cell-multiplication is the main factor in growth. The most characteristic feature of a growing organism is that it is normally self-

regulated. In the beautiful growth of a crystal in the midst of its solution, there is some degree of regulation in relation to the already existing architecture. Although we may not understand much about it, we see that the growth of the crystal is not higgledy-piggledy addition, but an orderly and proportioned crystallization. But this is far more deeply true of organic growth, which implies a *regulated* series of phenomena, occurring in a certain sequence and within certain limits. If the sequence be disturbed or the limits be crossed, then there is something abnormal. The regulation is comparable to that which we see in the erection of a properly-designed building—there is a style and a plan to be adhered to, there are laws of proportion to be respected, there is even a normal rate which must not be disregarded. In the same way, the regulation of organic growth has reference to the specific constitution of the organism (its structural organization on the one hand and its characteristic metabolism on the other), and that means that it has reference to the past history or evolution of the organism. This subtle quality of regulatedness is one of the criteria of organic growth, and it seems to many biologists to remove it far from the mere multiplication of chemical substances, or from the continued action of a ferment as long as material to ferment is supplied.

One of the ways in which the regulation of growth is brought about within the organism is by means of internal secretions or 'hormones'. These are produced by glands or glandular tissues in various parts of the body, and are passed into the blood. They are transported hither and thither and, when they come into close quarters with susceptible parts, they stimulate or hinder growth. Thus

it is well known that the internal secretions of the thyroid gland which lies on each side of the larynx (or 'Adam's apple'), and of the pituitary body (a remarkable organ which is appended to the floor of the brain) have a specific regulatory effect on the growth of the brain, the subcutaneous tissue, and the bones. It is said that a youth who had been a successful candidate for a military post, but was debarred because of inadequate height, was able by a judicious use of pituitary extract (obtained from ox and sheep) to add in a few months the peremptorily required cubit to his stature. It has been shown that the internal secretions of the reproductive organs in vertebrate animals have a specific effect on the growth of various parts of the body, both of important organs, like the milk-glands in mammals, and trivial decorative structures, like the comb in poultry. It seems certain that some, if not all, human giants are the result of the exaggerated secretion of the pituitary body, and it is possible that some kinds of dwarfs are due to a deficiency of the same stimulus.

Even when we cannot at present suggest a physiological interpretation, such as the influence of a specific secretion, the *fact* of the regulation of growth must be recognized. Different parts grow at very different rates, yet the normal result is proportionate growth. In cases of under-feeding, there is great diversity in the effect on different organs; they do not suffer alike. This points to a remarkable internal regulation of growth. More familiar, and perhaps simpler illustrations of the internal correlation may be found in cases where an organ, such as the heart, responds by increased growth to increased demands upon it.

Galls are often formed by plants in response to some external stimulus, such as the salivary secretion of the larval

gall-insect which has emerged from its egg-envelope deposited within the tissue of the leaf or stem. In these cases we have very striking instances of specific secretions inducing specific kinds of growth. These are extraneous secretions introduced into the plant by an animal, but we have also evidence of intrinsic secretions within the plant which help to regulate growth. Thus it is said that in the growth of the roots of some plants, specific chemical substances are formed which inhibit further growth. In short, facts are accumulating which show that particular parts of an organism have their growth regulated by specific internal secretions.

In his *Principles of Biology* Herbert Spencer devoted much attention to the conditions of growth. He sought to show that growth varies—other things equal—(1) directly as nutrition, (2) directly as the surplus of nutritive income over expenditure, (3) directly as the rate at which this surplus increases or decreases, (4) directly (in organisms of large expenditure) as the initial bulk, and (5) directly as the degree of organization. This kind of analysis is valuable, but what is more needed at present is an extensive series of measurements of growth under diverse conditions and in different kinds of organisms.

It is interesting to inquire into the *periods and rates of growth* in different organisms. After an egg-cell has been fertilized it divides and re-divides, but for a time, though there is increase in the number of cells, there is no increase in size. We see development, but no growth. Soon, however, development and growth proceed hand in hand, both very rapidly. Later on, when development is proceeding slowly—all the chief steps having been taken—growth may still continue very vigorously. Thus in the

pre-natal life of man, great strides in development are taken in the first three months, along with very rapid growth. Thereafter, when the developmental steps are much less striking, the growth is for a time very rapid. From the third to the fourth ante-natal month, the increase is 600 per cent. After this it drops quickly and is barely 25 per cent. in the last month before birth.

In some organisms the growing period is very sharply punctuated; thus in insects with complete metamorphosis all the growing is done in the larval period. After the fully-formed winged insect emerges from the pupa-stage, there is no increase in size. This holds good in all butterflies and moths; ants, bees, and wasps; beetles; and two-winged flies. In many cases the adult does not feed at all, and there is the sharpest contrast between the larva which feeds, grows, stores, and moults, and the adult or imago which does not grow or moult, but is especially concerned with the continuance of the race.

In other cases growth appears to have no limit but the length of the life-tether. As long as the organism lives and feeds it may go on growing. Thus we may distinguish the indefinite or indeterminate growth of fishes and reptiles from the definite or determinate growth of birds and mammals. A sacred crocodile may continue slowly growing year after year, and, it is said, decade after decade. It is not uncommon to get huge haddocks as large as good-sized cod-fish, but there is very little variation in the size of a sparrow or of a squirrel. In other words, some organisms show a very definite *limit of growth*—the physiological optimum—while others do not.

An interesting feature about growth is the occurrence of minor periodicities. Partly no doubt because of its

dependence on nutrition and on external agencies, growth is often *punctuated* in some detail. Every one is familiar with the annual rings of growth seen on the cross-section of a tree—seen so clearly because there is an alternation of summer wood and autumn wood differing in texture. The more prominent lines on the shell of the freshwater mussel indicate years and the weaker lines between these indicate minor periodicities. But the finest registering is seen on the scales, in the ear-stones, and even in some of the bones of many fishes.

Besides the periodicities of growth which can be reasonably correlated with external periodicities, such as those of the seasons, there are others of a more recondite nature, such as phases of quick growth and slow growth, that alternate in the development of some animals, as Fischel has shown, for instance, in the development of the duck. It is probable that these differences of rate are connected with the periodic liberation of internal secretions within the growing organism.

The rate of growth has been carefully studied in a few cases, *e.g.* in guinea-pigs by Minot, and the facts are striking. In guinea-pigs there is in both sexes a decline in the growth-rate almost from the moment of birth. The decline of *rate* is rapid from about the fifth day to about the fiftieth; from the fiftieth day onwards the decline is slower, until the growth stops altogether. Of course the animal is growing a great deal, and very quickly too, in its early days, but the rate of growth gets less and less. Moreover, the post-natal decline in the growth-rate appears to be a continuation of an ante-natal decline. As Dr. Jenkinson puts it, ' The younger the animal, the faster it grows; the more developed it is, the more slowly it grows. The

rate of growth, in fact, varies inversely with the degree of differentiation'.

In Man there are three maxima of rate of growth. The first is before birth, but its precise occurrence is uncertain. As we have already mentioned, the increment from the third to the fourth month is 600 per cent. It then falls with great rapidity between the fourth and sixth months, and thereafter more slowly till birth. The second maximum is in the first year of infancy, when the increase of weight is (according to Minot) about 200 per cent., and the length (according to Schwerz) increases from 50 centimetres to about 75 centimetres. In the following five or six years the rate of growth becomes slower and slower. The third maximum is towards the time of puberty, at about the age of twelve to thirteen for girls, of fourteen to sixteen for boys. In the early years the length of the body increases more rapidly than the weight; later on, after puberty, increase in weight takes the lead.

An interesting point in regard to growth is, that it may differ markedly in the two sexes. The male is often a pigmy compared with the female, though the egg-cells from which they developed may have been identical in size. The growth of women is quite different from the growth of men, and as this has been observed in all sorts and conditions, in many countries and races, it cannot be referred to differences in habits. It is a constitutional difference. It is not merely that the growth of women is 7 per cent. less than that of men; the growth is on a different scheme, with the parts in different proportions.

When we say that growth is a *regulated* increase in the amount of living matter, we mean that it is not a steady continuous increase in proportion to the available nutritive

income, but a periodic controlled increase, differing in its rate in different species and at different times, and proceeding in such a way that what we call proportion is secured. Professor Kellicott, in an important contribution to the theory of growth, has emphasized the same idea by calling attention to the diversity in the rate of growth of different parts of the body.

In the smooth dogfish (*Mustelus canis*) the various organs, or perhaps tissues, seem to grow characteristically, each having an individual form of growth curve. The rates of growth of the brain, the heart, the pancreas, the spleen, and so on, are different from the rate of increase in total weight. Indeed, it seems to Professor Kellicott that in fishes, which are organisms of indeterminate growth, the brain, heart, digestive glands, and fins do not always keep pace with general increase of trunk musculature and connective tissue, and a loss of functional equilibrium results. The fish may grow too large for its heart or for its brain. It cannot be doubted that the determinate growth of birds and mammals is an improvement on the more primitive unlimited growth of fishes, which is less perfectly regulated.

When we consider growth in its entirety as a regulated self-increase of the whole organism and of its parts, we see how far it lies beyond the present limits of physico-chemical interpretation. The analogous phenomena of chemical polymerization and of the increase of crystals in a solution are certainly interesting, but they do not seem to have brought us more than a little way nearer understanding organic growth. That an organism should keep its own diary, entering therein its tradings with time, is just a particular case of what is either a wonder or a commonplace, that a living creature is characterized by this

capacity of enregistering within itself its experiences. In many cases we do not know enough to read the diary; in many cases the creature destroys its own records in the continuous process of self-repair or of replacement of old cells by new. Here we feel the extraordinary importance of the fact that in higher animals there is no replacement of nerve-cells. We cannot add to them after we are born.

Young Animals.—In his remarkable book on *The Childhood of Animals*, which can hardly be over-praised, Dr. Chalmers Mitchell suggests a threefold classification. There are young animals which are in a general way like miniature editions of the parents, or which, at any rate, very soon become like their parents, as is the case with reptiles, birds and mammals, and with a great variety of backboneless animals, such as cuttlefishes, snails, spiders, and earwigs. There is a distinct youthful period, with interesting growth-changes, but young and old are of the same type.

In the second place, there are animals whose young stages are very unlike the parents, with a different kind of bodily structure—sometimes on a quite different plan—and with well-finished adaptations to a mode of life very different from that of the adults. Tadpoles are very different from frogs, and caterpillars from butterflies. The young of the sedentary water-bag-like sea-squirts are free-swimming creatures like miniature transparent tadpoles, and no one who did not know could guess that the 'Glass-crab' larva would become a rock-lobster. These larval forms are of great biological interest, and their marked unlikeness to their parents reaches a climax in most of the Echinoderms—(starfishes, brittle-stars, sea-urchins, sea-cucumbers, and feather-stars), where the free-swimming

pelagic stage is utterly different from the adult type. After developing for a while on a line of its own, suited to pelagic life, it begins again, as it were, on a new tack, and the development is strikingly circuitous (Figs. 69, 70). Many a young animal received a name of its own, before zoologists recognized its beginning or its end. Thus the knife-blade-like stage in the life-history of eels was called Leptocephalus.

The third group, according to Chalmers Mitchell, includes those animals which have no youth, and these he illustrates by simple creatures like Amœbæ. In such cases the unit which starts on an individual life of its own is already perfect; it does not differ in protoplasmic organization from the parent cell from which it was derived. We are inclined to think that it would be equally accurate to say that these simple creatures never grow up, remaining eternally young. Ageing began when a body began.

When we think over our experiences of young animals, a number of lasting impressions assert themselves. There is the extraordinary abundance of life, the multitudes of 'water-babies', like gnats and fish fry and tadpoles, and of terrestrial forms, like grubs and caterpillars and mice; there is the correlated impression of the abundance of death, out of a million oyster-embryos but one survives; there is the plasticity or modifiability of young things, the experimental tricks that can be played with tadpoles, for instance, being notorious. Another impression we get is, that the young creature does often in some measure climb up its own genealogical tree, for there is a great truth in the seductive and much-abused doctrine of recapitulation. Many reservations must be made, *e.g.* that the living creature is *specific*, itself and nothing else from first to

last; but especially in the making of organs do we see a succession of individual stages which seem to correspond to racial steps. The doctrine requires careful handling, but we think that the facts still warrant us in upholding a cautious statement of the 'Recapitulation Doctrine'—that the individual development of an organism is in some respects like a recapitulation, often much condensed and telescoped, of the historical evolution of the race.

In our *Biology of the Seasons* we have referred to another general impression which arises from the study of young animals—we are face to face with organic inertia on the one hand and organic divergence on the other. On the one hand, like tends to beget like; 'the child is as old as its parents, a chip of the old block, a pendant from a continuous chain of germ-cells'. On the other hand, we see 'the tendency to vary, to be something new, to be creative. The living creature is a Proteus. In a deep sense, the little child leads the race'.

The old-fashionedness of young animals is often well illustrated by their colour and markings. They tend to show the primitive kind of colouration that results from general physiological conditions, and the markings that result from the rhythms of growth. This colouration may be quite useful to the young animals, it often seems to give them a garment of invisibility; but it is primarily a result of constitution, and no more utilitarian than ripple-marks on the shore. Chalmers Mitchell shows that if there are changes in subsequent development they are usually of two kinds—(1) there is a blurring of the original pattern and a toning down of the youthful spottiness and emphasis, for in the adult struggle for existence there are few things safer than the monotony of 'self'-

colour; or (2) there is an overlaying of the old colouring and pattern by something distinctively new, 'ruptive', as he calls it. The new types of colouration are increasingly utilitarian and are proportionately defined by Natural Selection. We say 'new', but what occurs is probably an analysis of the 'old'; certain factors come to the front and others recede. Chalmers Mitchell uses the very instructive analogy—perhaps, as he hints, much more—of the dull coal-tar residues from which have been analysed-out the all-too vivid aniline dyes. In various passages, somewhat neutralized (we think) by others, Darwin suggests the view which many of his disciples hold (sometimes as if it were their own), that the colours and patterns of animals are outcrops of the dynamic constitution of the creature, or by-products, it may be, of its activity; but that what happens and has happened in Nature's sifting may be described as an elimination of the fatally exuberant or conspicuous.

The Purpose of Youth.—As we ascend the scale of animal evolution, we find that one of the tendencies, most notable in Mammals, is to lengthen out the duration of youth. All sorts of devices and precautions conspire to secure that the young animals remain longer young—fed, protected, freed from care and responsibilities, dowered with energy, and given opportunity to play. We owe to Groos, in particular, the idea that the play-period is the educative period in the truest sense, and of fundamental importance to the subsequent life.

We have discussed the matter recently in our *Biology of the Seasons*.

'There are many play-instincts among animals; they have been wrought out in the course of ages, partly

as safety-valves for overflowing energy, partly as the muscular correlates of emotion, partly as opportunities for the emergence of variations before too rigorous selection begins, but mainly as periods for educating powers which are essential in after-life. Animals, Groos says, do not simply play because they are young; they continue young in order that they may play. For play is the young form of work, and the animals who played best when young, worked best, lived best, perhaps loved best, when they grew up'.

In his *Childhood of Animals* Dr. Chalmers Mitchell has worked out the important thesis that the purpose of youth is to give time for the breaking down of rigid instincts, and their replacement by actions controlled by experience and memory, by remembered results of experiment. We would suggest that youth is the time when co-ordinations are established between the instinctive processes of the lower brain-centres and the intelligent processes of the cerebral cortex.

It is plain that youth is a perilous time; why should there be this tendency to lengthen it out? The answer is that it is the time for self-expression. The number of brain-cells does not increase, but their interlinkings are complexified, which means a growth of intelligence and a deepening of feeling. Thus has youth been justified in the past; so it is justified every day.

If Natural History is asked to give hints to the human educationist—and stranger things have happened—one of them will be this, as Chalmers Mitchell puts it:—

'Youth should be spent in blunting [a term apt to be misunderstood?] every instinct, in awakening and stimulating every curiosity, in the gayest roving, in the wildest

experiment. The supreme duty of youth is to try all things '.

Finally youth passes into adolescence. This is an arc on the up-grade, when juvenile characters are shed and adult characters put on. There is a final acceleration of growth (with correlated rest and play, and plenty of food); there is internal rearrangement and readjustment; there is a sifting of idiosyncrasies, to wit variations; there is a criticism of that acquired veneer which we call modifications or individually acquired characters; and there is more than a beginning of sex-impulses.

Courtship among Animals.—In the lower reaches of the animal kingdom the process of reproduction is often extraordinarily wasteful. Myriads of eggs are sown broadcast upon the waters, and millions of sperms are shed fortuitously. Many fishes produce several millions of eggs, and there is no counting spermatozoa. Mr. Oswald H. Latter has given a vivid description of the discharge of spermatozoa from the male freshwater mussel. It may serve to illustrate the prodigal wealth of reproductive material. A specimen of *Unio pictorum* emitted from the exhalant aperture between the shell-valves a fine double cloud of milky substance, which rose nearly to the surface of the water, and then fell as a diffused cloud. The whole of the water in the aquarium became cloudy and the emission continued for some hours. It appeared to be under some control, for a slight shaking of the floor was followed by a cessation of the streams of spermatozoa, though the ordinary exhalant current of water appeared to continue without interruption. The liberated material consisted of myriads of sperm-balls, revolving and swimming like Volvox-colonies, and finally breaking up into the

component spermatozoa. These exhibited astonishing activity, and some kept it up below a cover-slip for seven hours after liberation.

Many of the lower animals feed easily and have much to spare, so that they can afford to be prolific. Moreover, until the nervous system reaches a certain degree of integration, the sexes cannot be definitely aware of one another. In Echinoderms, for instance, the absence of ganglia puts definite sex-awareness out of the question. At many different points, however, in the ascent of life we find economization of reproductive material. An incipient case is familiar in the salmon. The female fish makes a furrow in the gravelly bed of the river and lays her eggs there. The attendant male is stimulated by the presence of the mature female and her eggs, and liberates the sperms or milt along the furrow. There is still great loss, but it is the beginning of an improvement upon the primitive and wasteful broadcast semination of the waters.

Along various lines of animal evolution we find that the males and females have become very definitely aware of one another and are excited by one another. There is a by-play of amatory behaviour preliminary to pairing, and probably rendering the pairing more effective. A pervasive excitement may change the creature's character and appearance; the whole being is sometimes, as it were, transfigured. There is often a seeking out of the females by the ardent males, and occasionally there is an appeal made to the males by the females. The excited males fight with one another, sometimes with almost maniacal ferocity, sometimes in a half-playful, bloodless jousting. Again, in a fascinating variety of ways, the males make displays—of agility, of mettlesomeness, of beauty, of fragrance, of

musical talent, and so forth—before the senses of their desired mates.

Mr. W. P. Pycraft's recently published charming volume on *The Courtship of Animals* gives an admirable discussion of the whole subject, with a wealth of fresh instances, and we shall not do more than recall a few pictures. Stag fights with stag till they drip with blood; the rival

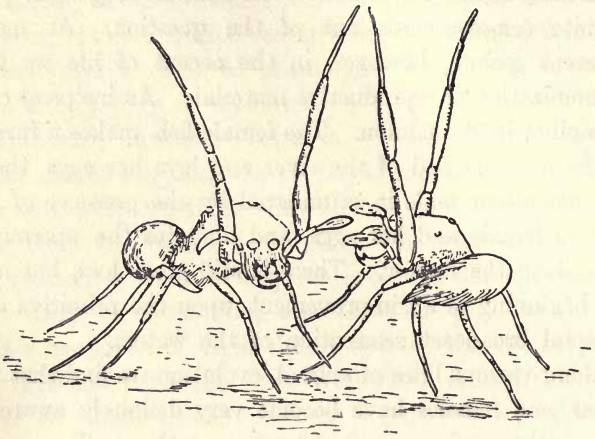


Fig. 62.—Male Spiders (Zygoballus) fighting. (*After* Prof. and Mrs. Peckham.)

sea-lions slash with their great canines at one another's necks, making long wounds, as the scars show for many a day; the cock capercailzies fight in the early spring and the snow is spotted with their blood; the blackcock's tournaments at dawn are revelations of mingled passion and pride; the polygamous ruffs fight hour after hour without wounds, and mingle their pugnacity with an extraordinary self-abandonment; male spiders have similarly bloodless battles. When there is actual elimination of the

weak, the cowardly, the clumsy, the dull, and so on, so that they are definitely unsuccessful or less successful in reproduction, the combats of the males will probably have some direct evolutionary influence, as Darwin confidently believed. But there is great need for a stern sifting of the data and an accumulation of more.

On the other side, there is the great variety of peaceful

FIG. 63.—Male spider (*Icius mitratus*) dancing. (*After* Peckham.)

ways in which male animals give expression to their emotions in the presence or proximity of their desired mates. Many male spiders have a characteristic love-dance, differing for different species, in which they appear to our eyes as if they were showing off their good points. Some insects have luminous love-signals, many offer up fragrant incense, many give themselves up to energetic serenading—if we may so call it in our almost complete absence of knowledge in regard to the sense of hearing in insects. Many birds make elaborate displays, bending and bowing, strutting and saluting, circling and fluttering; and even a few of the

cold-blooded fishes and newts have their love-play. Finest and most familiar is the musical appeal of many birds.

Thousands of interesting facts are known as to visible behaviour, but it is difficult to judge of the inward spirit. We must not be recklessly generous, nor materialistically sceptical. The whole life is one, and while we know that internal secretions or hormones, liberated at the breeding season and pervading the whole body, influence the brain and the whole nervous system, and the circulation of the blood and its composition, we are not on that account to suppose that the bird on the bough is emotionless, like a musical box. We must not read too much into the displays, for the suitors are, as it were, sex-intoxicated, expressing their ardour instinctively and with abandon, rather than with deliberation or strategy, but we must not think of them too cheaply, as if they expressed lust only, and no love.

As to the evolutionary importance of the courtship behaviour, there is need at present for a critical revision of the data. The late Alfred Russel Wallace always insisted, thus differing from Darwin, that there was little convincing evidence that the female bird chooses her partner, or chooses him because of any particular excellence in colour or plumage, agility or musical talent; but some good ornithologists bring forward circumstantial cases of unattractive male birds being left unmated. More facts are needed.

While Darwin seemed sometimes to credit the females with a high degree of taste or æsthetic fastidiousness, he was probably on safer ground when he wrote: 'It is not probable that she consciously deliberates; but she is most excited or attracted by the most beautiful or melodious or gallant males'. The probability is that the female surrenders

herself, not to a male selected because of some particular excellence, but to the fortunate fellow whose ensemble most successfully excites her sexual interest. Now, if this be so, and if a number of uninteresting males are definitely unsuccessful or less successful in reproduction, there will be, in some measure, a defining of the path of evolution. There will be not only a toleration, but a favouring of beauty; there will be at least a handicapping of dullness.

Looking over a treasury of illustrations, such as Mr. Pycraft's *Courtship of Animals* contains, we cannot but ask what the deep significance of the whole elaborate system of behaviour may be, for it is not enough to say that it is simply an overflow of vital energy and *joie de vivre*. The persistence of a race depends on the success with which it continues its kind, and the sex-impulse with its urge has made reproduction a certainty. The instinctive behaviour of courtship has added to the force and subtlety of the overmastering internal sex-impulse. Indeed, as Emerson said, the sex-impulse is imperious so that reproduction may be ensured. As a matter of fact, we should turn the idea round a little, and say that those types have survived in which the sex-impulse was strong; but it comes to the same thing. Groos has pointed out that coyness on the female's part is a character of considerable racial value, and the courtship allows of coyness because the fittest males succeed in overcoming it. Our general conclusion is that the deep significance of courtship-behaviour is that it makes pairing more effective.

In Illustration.

Sea Lions.—In Spring a few old male sea-lions make their appearance at the Pribylov Islands and swim about

for several days, prospecting. They examine the 'rookery' and go off to sea again, returning in reinforced numbers. Each male chooses a spot—some thirty yards square—for his future harem, and jealously guards it against intruders. About two months later the females, who are not nearly so large as the males, appear on the scene, and there is great competition for them, each 'polygamous sultan' trying to secure from fifteen to twenty wives. Accounts differ a good deal as to the degree of 'give and take' among rival males. The cubs are born a few days after the arrival of the mothers, and seem to require a good deal of education. Soon after the birth of the young, Professor D'Arcy Thompson tells us, 'the comparative quiet of the rookery is exchanged for a babel of noise and incessant quarrelling.' The old males try to add to the score or so of wives they have apiece; the wifeless younger males try to secure mates; there are great fights among rival bullies. 'So all day long the noise of battle rolls along the beaches by the wintry sea, and the growling and the snarling, the confusion and the din, are for some weeks together indescribable'. The younger males, or bachelors, herd apart from the others, and both they and the married females go down to the sea to feed. It is noteworthy, on the other hand, that 'the old males starve rather than leave their posts; they come fat and vigorous in springtime, and are gaunt, emaciated, and scarred with the scars of many battles before they leave again in autumn'.

Fragrance.—In many butterflies, such as the green-veined white (*Ganoris napi*), the males have a distinct flowery perfume, which is associated with remarkable 'plume scales' on the upper surface of the wings. It is readily perceptible if we rub the wings with a camel-hair

brush. Similar perfumes, almost always flower-like, are well known in relatives of the common whites, and they are almost invariably confined to the males and to the upper surface of the wings. The cells that produce the scent—which may be of the nature of a volatile oil—seem to lie in the skin (or hypodermis) below the surface-membrane of the wing, and the 'plume scales' are only distributors. There can be little doubt that Fritz Müller's suggestion is correct, that the pleasant flower-like scents are useful to the males in their courtship of the females, as auxiliary means of attraction. It may also be that they help members of the same species to recognize one another, for the perfumes are often exceedingly distinctive or specific. As to the repulsive scents, there is definite evidence that they help to protect their possessors from insect-eating enemies.

Fire-Flies.—We have already referred to the courtship of the Italian Fire-fly. The female, sitting among the grass, signals to passing males, who respond and settle down around her in a devoted circle. Flashes of light pass from the suitors to the object of their desire, and from her to them, till the fire is sufficiently fanned, a pairing takes place, and the party breaks up. Not less refined is the approach that some male spiders make to their somewhat explosive mates—vibrating with one of their appendages one of the threads of the web on which the exquisitely sensitive spinner sits.

Audible Signals.—Dr. Karl Peters has given us a very interesting picture of love-signalling on the part of an Alpine moth (*Endrosa* or *Setina aurita*, var. *ramosa*), which he studied at Arolla. The males fly about actively, but the females are sluggish and rest for the most part on

tussocks of grass, where they are very inconspicuous. The males are able to produce a crackling or snapping sound, and it seems as if the females responded to this signal by vibrations of their body and wings. When the males fly overhead or settle down in the vicinity, the females make themselves more conspicuous by their tremulous movements, which appear to attract the male's attention. When the sound stops, the answering movement stops. Even when the female cannot see the male, she answers back when the sound begins. It seems, then, as if the male's signal appealed to a hearing organ and the female's signal to sight. Dr. Peters's observations are of great interest, because the experiments that have been made to test the auditory powers of insects have been very unsatisfactory. It is difficult to believe that the instrumental music of Cicadas and crickets falls on deaf ears, but the experiments testing this are inconclusive. Insects that have been credited with the power of hearing remain quite indifferent to a great variety of sounds, but it is possible that the experiments fail because the sounds used as tests have been meaningless and therefore quite uninteresting to the insects. More observations like those of Dr. Peters are much to be desired.

Puzzles of Behaviour.—The Praying Mantis, or Prègo-Dieu of the Provençals, is a ferocious Carnivore in a vegetarian order (Orthoptera), and feeds exclusively on living victims, such as crickets, which it seizes by the back of the neck. Fabre has shown that in comfortable captivity, with abundant food, the mature females fight fiercely and devour one another. The males likewise, smaller and more delicate than the females, are often devoured by their mates, after having had their addresses accepted.

'In the course of two weeks,' Fabre writes, 'I have seen the same Mantis treat seven husbands in this fashion. She admitted all to her embraces, and all paid for the nuptial ecstasy with their lives'. But we must remember that these same female Mantises make a beautiful and elaborate cradle for the eggs, beating up a somewhat silken secretion into a spongy foam which hardens in the air.

The same mysterious 'post-matrimonial cannibalism' is illustrated by some scorpions and spiders, by some crickets, and by the so-called 'golden' Scarabee beetle. It must be remembered, however, that most of the records relate to creatures in captivity. Fabre relates in regard to the 'golden Scarabæus,' which does such good work in destroying caterpillars that creep on the ground, such as the procession caterpillar, that between the middle of June and the first of August, twenty-five comfortably-cased Scarabees were reduced to five—all females. He saw one of the females devouring a male, and he found that all the corpses of the males had been eviscerated. The fact that the males did not seem to resist, suggests that they may be naturally moribund after mating.

Parental Care and the Family.—In many animals, from worm to frog, the mother discharges a large number of eggs, and leaves them to develop. Sometimes, indeed, as in some marine worms and in many butterflies and moths, she dies soon after reproduction. Even in strong animals like lampreys and eels, death seems to follow like a nemesis close on the heels of reproduction. It must be admitted that the liberation of huge numbers of ova—sown broadcast in the waters—is a wasteful process. There is great mortality and many of the eggs are

not even fertilized. The race is continued because there are so many.

One must never think of Nature as deliberating and deciding to replace a wasteful process by a more economical one, nor yet as simply drawing her bow at a venture and in the course of time hitting a mark. What goes on is a ceaseless experimenting in different modes of self-expression. Less prolific forms arose, and those that instinctively took some care of eggs or offspring tended to define the direction of evolution. Sometimes, on the other hand, more careful types arose—resting exhausted beside their mass of eggs, and by and by incubating them—and those that were more economical in productivity would tend to define the direction of evolution. The process may have worked either way.

A number of suggestions may be offered. (1) The passage from aquatic to terrestrial life is associated with internal fertilization and with the suppression of larval stages (see Chapter II), and it follows that the mother animals would come to have a longer organic acquaintance with their ova. The bird laying her eggs is much more aware of what she is doing than the fish in the sea. (2) In certain conditions, such as the low temperature of the abysses or of polar seas, growth processes are slowed. This might lead to a longer retention of the ova within the body, and to viviparity. It is very significant that in Antarctic Echinoderms, for instance, there is a general, though not complete suppression of free-swimming larval stages, and many cases are known of parental care, differing curiously in details. (3) As is usual, when we face such problems, we find that there are many approaches to parental care and family life. The goal was probably reached very

gradually and by various routes. Thus we see a beginning in those cases in which the mother lays her eggs, instead of merely liberating them. The female salmon lays eggs in a furrow which she makes in the gravelly bed of the stream. We see a beginning in those cases in which the mother carries her eggs about with her after she has liberated

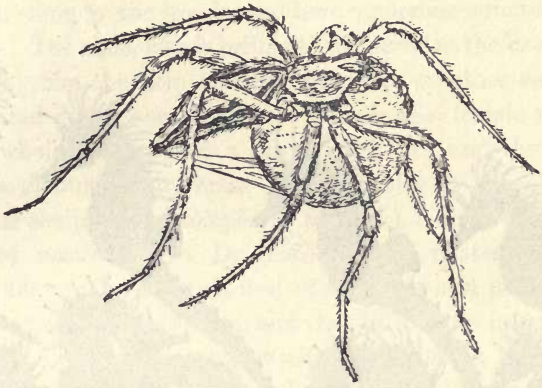


Fig. 64.—Female Spider—Dolomedes mirabilis—carrying underneath her body, attached by silk threads, the silken cocoon containing the eggs and eventually the young spiders. (*After* Blackwall.)

them. Many a spider has a silken cocoon which she bears about with her until the spiderlings hatch. We see a beginning in the retention of the eggs, not only until they become larvæ, but until particular circumstances arise. Thus the freshwater mussel, which we have discussed, keeps its Glochidia in its gill-cradle until a minnow or the like comes conveniently into the vicinity. We see a beginning in the way many an animal mother allows her young ones to clamber about her body, holding on to her and being protected by her. The generalization may be

ventured, that the maternal care is in certain respects like an external continuation of the internal organic linkage.

Paternal Care.—Some of the backboneless animals which show parental care are hermaphrodites. This is true of the brook-leech (Clepsine), which carries about its young ones on the under surface of its body. In other cases, both of high and low degree, the parental care is

FIG. 65.—Sea Horses, Hippocampus. The upper row shows the successive positions of the body in swimming. The body bends forwards and straightens again. The lower row shows the fishes at rest. (*After* Anthony and Chevroton.)

exhibited by the males. We find this among those interesting animals, of uncertain zoological position, known as sea-spiders or Pycnogonids, where the males carry the eggs attached to two of their legs. We find it in several fishes, such as the stickleback, who makes and guards the nest among the sea-weed, or the sea-horse (Hippocampus), who

carries the eggs about in his breast-pocket. The same is true of some pipe-fishes (Syngnathus).

Somewhat like the stickleback's nest, but made by the female, is that of the kelp-fish (*Heterotrichus rostrata*) of the South Carolina kelp-beds. Mr. C. H. Holder observed a female in captivity, and saw her push her way through and round a bunch of seaweed, depositing a white viscid cord, which clung to the fronds, and bore numerous minute white eggs. The male, who is brilliantly coloured at the breeding-season, like the kelp and like his mate at other seasons, mounted guard over the 'nest', while the female rested. The whole process took a couple of hours, and the result was a globular white mass about the size of a hen's egg. Of the sculpin (*Myoxocephalus scorpius*), a common shore-fish of northern seas, Dr. Theodore Gill relates that the male may make a rough nest of seaweeds and pebbles for the reception of the spawn, and that he mounts guard over the mass of eggs, clasping it with its fins for a long time.

In the case of *Arius fissus*, a shore fish from French Guiana, about twenty eggs ripen at one time. When these are laid, the male takes them into his mouth, where they remain until after hatching, until, in fact, the yolk sac is absorbed. During the whole of this incubation period the father fish is condemned to fast, so that we have a somewhat whimsical instance of that antithesis between nutrition and reproduction which echoes through life.

Among Amphibians there are many cases parallel to those which occur among fishes. Thus the male nurse-frog (Alytes), not uncommon in some parts of the Continent, carries the strings of ova on his back and about his hind legs, buries himself in the damp earth until the development of the embryos is approaching completion, then plunges

into a pool, where he is freed from his living burden. In the case of the Surinam toad (Pipa), the male is said to help the female in placing the eggs upon her back, where each sinks into a little skin pocket, in which it develops without passing through a tadpole stage. In Nototrema the female has a dorsal pouch opening backwards, and into this the male pushes the eggs with his hind legs. In a little South American frog, Darwin's Rhinoderma, the male carries the (5–15) ova in his croaking-sacs, which become enormously enlarged in the course of their development. Eventually miniature frogs jump out of the father's mouth! In a number of birds the incubation is shared by both sexes; in the American ostrich (Rhea) it is said to be wholly discharged by the male.

When we see the male lumpsucker or cock-paidle (Cyclopterus) mounting guard over the mass of eggs in the rock-pool, and keeping them clean and aerated by frequent agitations of the water, and continuing at this

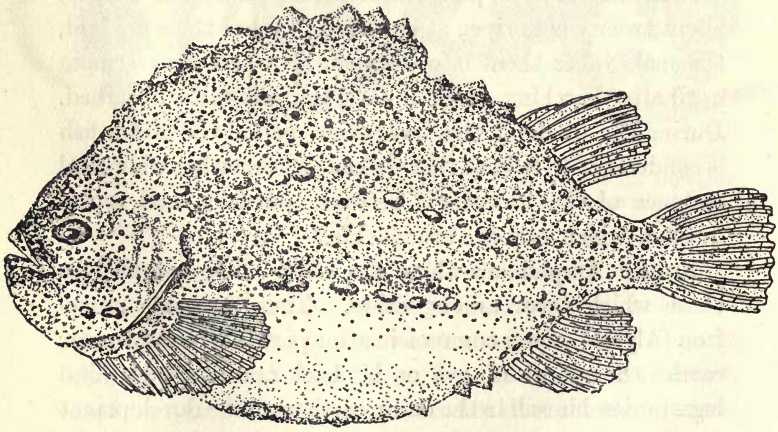


FIG. 66.—The Lumpsucker (*Cyclopterus lumpus*). From a specimen.

task for many days, we are undoubtedly face to face with parental care, and we are surprised that it should be paternal. Two suggestions may be offered:—(1) that just as maternal care, in certain of its expressions, may be thought of as a sort of prolongation of viviparity, so paternal care may be organically associated with sex-instincts; and (2) that just as we find a female reindeer always with antlers and the female Red-necked Phalarope with masculine colouring and ways, so parental instincts which usually develop only in the females may, to suit particular needs, be grafted on to the males.

There is not much parental care among Gasteropods, but there are often very remarkable egg-cases in which the early stages of development are passed. We may refer in illustration to the American Slipper Limpet (*Crepidula fornicata*), which has spread rapidly since 1880 on British oyster grounds. It takes special care of its spawn, as Mr. Orton has told us.

'It constructs about fifty to sixty membranous bags, into each of which it passes about two hundred and fifty eggs, and as the bags are made and filled with eggs, they are closed and fastened together by short cords. These cords are finally all stuck on to the surface on which the slipper-limpet happens to be sitting, so that when by taking away the spawning individual the spawn is uncovered, it looks like a bundle of balloons, each containing a number of eggs'.

Fabre has described in his inimitable manner the behaviour of a Hymenopterous insect, the Bee-hunter (*Philanthus apivorus*), which pursues the hive-bee. It always stings the bee on a minute soft patch in the throat, which leads the sting into the cervical ganglia,

'abolishing life at a single blow'. There is a much larger soft area further back, but that is not utilized. It is a knock-out blow under the chin that is delivered. Clasping its dead victim firmly, the Philanthus squeezes out the honey from the stomach, and does so repeatedly till every drop is enjoyed. The fresh corpse of the bee is then given by the Philanthus to her grubs, to whom the honey is noxious!

In many insects the mothers exert themselves unsparingly to provide stores of food for the young, but participation on the father's part is very rare. Among the dung-rolling beetles there are exceptions—such as the Sisyphus, the males and females of which work together in kneading a pill of dung and transporting it, over great difficulties, to the underground burrow where the eggs are laid. In the case of the scarabee, Fabre tells us that while the sexes co-operate in rolling balls of dung for their own consumption, the female is left to do all the work of moulding the ball and transporting it when it is for the use of the future brood.

In non-social as well as social insects, parental care is sometimes exhibited. The quaint mole-crickets (Gryllotalpa) move their eggs in their underground nests according to the weather, and guard them sedulously against black-beetles and the like. The earwig sits on her eggs, and older writers have described what some who have recently watched earwigs carefully have failed to confirm, that the mother-insect gathers her young under her as a hen her chickens. In spite of Fabre's criticism, it seems likely that De Geer was accurate in his description of the mother birch-bug brooding over her eggs and young.

F. P. Dodd describes the brooding habits of one of the

bugs, *Tectocoris lineola*, var. *banksi*. The mother sits in a brooding attitude over her eggs for three weeks, until the young are hatched out. She does not have anything to eat during these weeks. When the young begin to break through the egg-shells, the mother backs away for an inch or so from off the egg-mass, and remains there for some hours, long after the last egg is hatched. She then departs, leaving the young bugs, whom she has perhaps saved from Ichneumon flies, to fend for themselves.

It is among birds and insects that we find the highest development of parental care, but what a contrast there is between the two expressions. Among insects the preparations that are made for the young are for the most part instinctive, and the mother is often without the satisfaction of even seeing her offspring—for she is dead before her eggs are hatched. Among birds, while instinctive behaviour continues, it is associated with much more intelligence, and the preparation of nest-making is followed up by the patience of brooding, and that again by often prolonged nurture, and even education. Many birds are careful in turning their eggs and in keeping the nest clean after the young ones are hatched. Of the nests of birds, what shall we say?—so many of them express a climax of art (both intelligent and instinctive) on the one hand and of instinctive altruism on the other. For artistic quality, take the nest of the wren, of the thrush, of the chaffinch, of the house-martin, of the bottle titmouse, of the tailor-birds, and of the weaver-birds. Or consider the single case of the sea-swift, which achieves the impossible by fashioning a firm nest out of the juice of its mouth. For altruistic quality, take MacGillivray's fact that he got 2,379 feathers out of the nest of the long-tailed tit, or the burrowing of

the sand-martin—an activity so alien to a bird's nature—or the labour of several months that is spent in building, pellet by pellet, the strong two-chambered mud-nest of the S. American oven-bird—an architectural masterpiece that may be as big as a child's head.

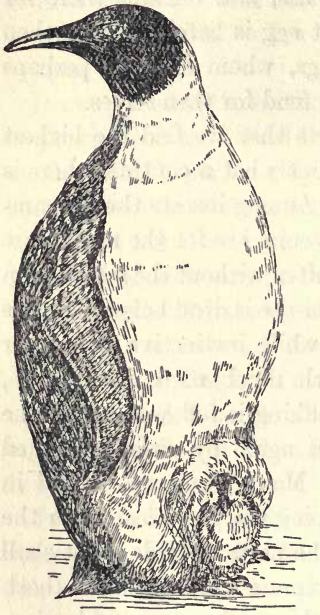


Fig. 67.—An Emperor Penguin, Aptenodytes forsteri, with the young one on her feet. (*After* Wilson.)

The brooding must imply a good deal of a quality allied to patience, and in many cases not a little of a quality allied to courage—when an enemy comes nosing all round about the nest. The shy curlew has been known to allow a photographer to bring a large camera within ten feet of her nest without betraying herself by the slightest movement. In some cases, e.g. of great heat, the brooding bird appears to suffer considerably, and perhaps this has something to do with the fact that birds almost always nest in the coldest part of their migratory range. The bird *has to do* all this, but the same may be said of much of the parental care which all the world admires in the human mother — it is instinctive. In Man there is probably greater possibility of disobedience and there is a fuller awareness of what it all means.

After brooding there is the labour of feeding the young, which often taxes to the utmost the energies of both parents. Miles away from the Bird-Berg, where tens of thousands of guillemots lay their eggs on the ledges of the cliffs, there is a 'bank' where sand-eels abound, and it is interesting to lie in a boat and see the constant double stream of birds passing overhead, all those returning to the cliffs having a glistening fish in their mouth. We do not know which most to wonder at, the appetite of the youngsters, the indefatigableness of the parents, or the supply of sand-eels.

We have already referred to the story of the hornbill. The mother-bird nests in a hole in a tree, and is imprisoned by a doorway of resinous material, big enough to let the male bird's bill in, but small enough to keep enemies out. On the male devolves the task of procuring food for his immured mate, and afterwards for his offspring also. After three weeks of it, he is often worn quite thin, and sometimes he actually succumbs to his other-regarding exertions before he is rejoined by the female bird. He *has to do it*—and it is said that an unrelated male will attend to a widowed bird—so that we may not be warranted in using big words like altruism in appreciating his behaviour. But no amount of scrupulosity can disguise the fact that his expenditure of energy is not for himself.

After the labour of feeding, comes the fine art of education, for the young bird has always a great deal to learn. Experiments in artificial incubation have shown conclusively that the young bird is not rich in inborn knowledge. The chick artificially hatched, with the aid of an inanimate foster-mother, has no instinctive recognition

of its actual mother's cluck. Even when thirsty it does not recognize water as drinkable stuff, not even when it walks through it. So unprejudiced is its *tabula rasa* of a brain, that it will stuff its crop with worms of red worsted. But the point is that it makes up for its paucity of instincts by an extraordinarily rapid educability. And that is what the parent-birds work with in educating their young in the ordinary conditions of wild nature.

As all Mammals except the primitive Monotremes are viviparous, their exhibition of parental care is perhaps not so striking as in the nest-building and brooding birds, but it often reaches a high level. We have to remember the often prolonged gestation—the mother carrying, as it were, a huge parasite within herself, the suckling of the young, and it may be carrying them about, as in Marsupials and Bats, the defence of the family, and their initiation into the business of life. Some Mammals, such as monkeys, have a prolonged infancy and a long gastric education on milk; others are quickly able to look after themselves. We read that a giraffe is able to stand up in about twenty minutes after birth, to run freely in a day or two, and to nibble grass in three weeks.

Chain of Parental Instincts.—There are many unsolved problems connected with parental care, but we think that Professor F. H. Herrick has made many points clearer by his conception of a chain or cycle of parental instincts, to which we have already referred in connection with the cuckoo (p. 320). The events in the cycle follow one another with almost clock-like precision, but are always liable to be influenced by intelligence. Normally they form a harmonious series, and, what is very important, there is an attunement—a time-keeping—between the

instincts of the parents and those of the offspring. Individual disturbances of the harmony or attunement are continually occurring, and are often misinterpreted as insoluble puzzles. In the cuckoos and cow-birds a remarkable change in instincts has been evolved as a *modus vivendi* to meet a disturbance of the time-keeping.

We give a shortened statement of Herrick's analysis of the reproductive cycle.

1. The spring migration to the breeding area or birthplace.

2. Courtship and mating, often attended by song and dance, especially in the male.

3. Nest-building :—(*a*) selecting a site or using an old one; (*b*) building the nest or adapting an old one.

4. Egg-laying, usually at daily intervals in the completed nest. As in (3), this is often attended by instincts of guarding, fighting and concealment.

5. Incubation or brooding instinct; attended as before by instincts of guarding, fighting and concealment; often, as it proceeds, allaying all fear; including a variety of instinctive acts, sometimes recurrent, as removal of eggs in bill, inspection of eggs, stirring of eggs with bill or feet, cleaning nest by removal of broken eggs or shells, shielding eggs from heat or cold, and sometimes hiding them with covering of wings.

PARENT.	YOUNG.
6. Care of the young—collecting food; feeding the young; inspecting the nest and nestlings; cleaning both; etc.	Initial responses at and after hatching; swallowing reflexes; call notes, and later alarm notes; burrowing under old bird; etc.

7. Care and 'education' of young, guarding, fighting for, feeding, encouraging, teaching, etc.	Flight, fear, seeking prey, giving call and alarm notes; following, crouching, hiding; imitating.
8. Autumn migration to winter quarters—singly, or in company with individuals of the same or of different species.	Migration with adults or independently.

Retrospect.—In the lower reaches of the animal kingdom there is prolific multiplication and great mortality; or, from another point of view, a life full of hazards and high reproductivity to cope with these. It has been one of the great steps in evolution to economize life, and one of the most successful ways of doing this has been by parental care, of which affection is a consequence. As Chalmers Mitchell expresses it: 'The mere toleration of the young by the mother is a new beginning in life, and is the foundation of many of the highest qualities displayed by the highest animals and by man himself'. . . . The relations of the young to the mother 'are a continuation of the organic relation by which the young are born of the body of their mother, and they exist and become, so to speak, a habit, before the individuality, the physical powers, and the senses and aptitudes of the young are really awakened'. . . . Later on we have, of course, affection as well as care; and families lead on to societies.

The Individual and the Race.—When we study the modes of multiplication, or the instinctive provision made for the young, or the more deliberate parental care of higher animals, we cannot but be struck by the fact that what is

done is often very far from advantageous to the *individual*. It is advantageous, indeed essential, for the species, but it is exhausting, sometimes fatal, to the single life. As Goethe said, Nature 'cares nothing for individuals'.

Animals do not indeed foresee that their reproduction is going to be fatal to them; the instinctive mother-insect does not know that she will never see her offspring emerge from the eggs around which she places a store of laboriously collected food; we have no reason to believe that she has any picture of offspring; when animals are fatigued, as their brain-cells show them to be, they probably suffer no weariness, and they are doubtless unquestioning; they are borne on by impulses and instincts which are as compelling as hunger and thirst. But the point is that these strong instincts bear them to expenditures of energy which are not self-preservative, but objectively other-regarding. In some cases, it is true, there is the reward of reproductive gratification, and Emerson was, we believe, profoundly right when he suggested that the imperiousness of sex desire was necessary in order to make organisms (especially the higher animals) face reproduction. But the reward of sex-gratification only applies to a limited set of cases, and even for it many animals have to pay heavily. As Goethe said: 'She holds a couple of draughts from the cup of love to be fair payment for the pains of a lifetime'. We are brought, then, to face the great fact of Organic Nature, that those forms of life tend to survive in which the individual has been more or less subordinated to the welfare of the species. Metaphorically, that is part of Nature's strategy. Literally, the prolific species-preserving types have survived.

Reproduction is physiologically expensive. The sturgeon,

whose unlaid eggs form the delicacy known as caviare, liberates more than a million. There may be 100,000 spermatozoa in a cubic millimetre. Many female butterflies die after oviposition, and the same is true even of robust animals like lampreys. The drone who succeeds in fertilizing the queen hive-bee dies as he succeeds ; all the others, who are unsuccessful, also die. A male spider often lays his life on the altar of sex, and the same is true of some scorpions. Viviparity is costly to the female, especially in Mammals ; parturition is often exhausting ; feeding the young is a drain on the mother's resources.

In a very interesting essay, *L'Espèce et son serviteur* (Paris, 1913), Professor Cresson has illustrated the degree to which the individual is subordinated to the welfare of the species. Apart from the physiological sacrifice alluded to, there is the energy expended in securing the safety of the eggs, and in providing nourishment for the young. In many insects, such as sand-wasps and scarabees, the amount of work done for the welfare of the progeny is very great. The non-existent offspring act, Cresson somewhat fancifully suggests, as ' moral parasites ' on their parents.

There is fatigue in nest-making, risk in incubation, and both in attending to the nourishment, health, and education of the young. Especially the mothers are, so to speak, exploited, Nature taking advantage of their capacity for self-forgetfulness. Less metaphorically, it is their meat and drink to spend themselves for the race. In the case of social insects, the subordination of the single life is extraordinary, sometimes almost pathological. Cresson, indeed, suggests the formula, ' Everything for the species ; everything by the individual ; nothing for the individual '.

Ageing and Senescence.—In most animals, as we

have seen, there is a definite limit of growth, which we regard as the fittest size for the given organization and the given conditions of life. Departures from the norm have been persistently pruned off in the course of Natural Selection. Similarly in many animals there is a normal length of life (a potential duration of life) which is rarely exceeded, though it may be seldom attained. Many of the facts in regard to unusual length of life refer to animals in captivity, and it is quite likely that a creature may survive longer in a sheltered life than when it is subject to the struggle for existence. On the other hand, the duration of life in captivity can hardly lead us to over-estimate the *potential* duration of life in nature, since the artificial conditions are bound to be less wholesome. The facts in regard to captive animals tell us that the creatures can live to such and such an age; but this may be far above their average length of life. It is very unlikely that many wild parrots approach the century which is their potential longevity. In the case of domestic animals, few fowls are allowed to survive for five years, though they might live for a score; few cattle are allowed to reach the end of their tether, which is about thirty; and just the same applies to the average length of life in Nature, since most wild animals come to a violent end.

Dr. Chalmers Mitchell's critical revision of the data available in regard to the duration of life in mammals and birds goes to show that most of the previous estimates have been too high. Though a hundred years may be the probable limit for the elephant, twenty to thirty years is a fair average duration. A polar bear lived to thirty-three years in the Zoo. The potential longevity of lions is between thirty and forty years; that of some of the largest Ungu-

lates about fifty. It is rather interesting that human longevity is probably greatest of all among mammals, with the possible exception of the large whales.

As regards birds, more than one centenarian parrot has been recorded, and the same age is credited to some birds of prey. A raven of sixty-nine is authenticated, and an eagle of sixty-eight. Herons, swans, and geese have a high potential longevity, and an ostrich is said to be capable of occasionally surviving for a term of thirty-five years. A giant tortoise (*Testudo gigantea*) that was living near Colombo in 1796, when Ceylon was first occupied by the British, survived until 1894, so that it must have been more than a centenarian.

In the case of Man, we must clearly distinguish between the *average specific longevity*, about thirty-four years in Europe—but happily raisable with decreasing infantile mortality, improved sanitation, decreasing warfare, increasing temperance and carefulness—and the *potential specific longevity*, which for the present race is normally between seventy and one hundred years. There is no warrant for fixing an ultimate limit, either for the past or the future. All that we can scientifically say, is that there are few well-established instances of a greater human longevity than 104 years. Sir George Cornewall Lewis did good service (1862) in destructively criticizing numerous alleged cases of centenarianism, the occurrence of which he at first regarded as quite unproved, but even he finally admitted that men do sometimes reach a hundred years, and that some have reached one hundred and three or four. The famous cases of Thomas Parr, Henry Jenkins, and the Countess of Desmond, said to be 152, 169, and 140 respectively, were ruled out of court by Mr. Thoms, who edited *Notes and*

Queries at the time when Sir G. C. Lewis's wholesome scepticism created much stir. As man is a slowly varying organism, as regards physical characters at least, it is extremely unlikely that his longevity was ever much greater than it is now. Monsters in age and monsters in size are alike incredible.

A fact of much interest is the statistical evidence that such a subtle character as 'longevity', that is to say, a tendency to a certain lease of life, be it long or short, is heritable like other inborn characters, though it rests of course to some extent with the individual or his environment to determine whether the inherited tendency is realized or not. Just as stature is a heritable quality, so is potential longevity, but the degree of expression is in part determined by 'nurture' in the widest sense.

Professor E. Metchnikoff is one of the few modern biologists who would deal generously with biblical and other old records of great human longevity. He apparently thinks there has been some misunderstanding in regard to Methusaleh's 969 years or Noah's 595, but he accepts the great ages of 175, 180, and 147 years ascribed to Abraham, Isaac, and Jacob. Similarly, he accepts the 185 years with which St. Mungo of Glasgow has been credited. And as he is generous in regard to the past, he is hopeful in regard to the future, believing that a more careful and temperate life, as well as an enlightened recognition of the disharmonies of our bodily frame, may bring about a time when man will no longer, as Buffon said, die of disappointment, but attain everywhere a hundred years. 'Humanity', Metchnikoff says, 'would make a great stride towards longevity could it put an end to syphilis, which is the cause of one-fifth of the cases of arterial sclerosis. The sup-

pression of alcoholism, the second great factor in the production of senile degeneration of the arteries, will produce a still more marked extension of the term of life. Scientific study of old age and of the means of modifying its pathological character will make life longer and happier '. He also quotes the theoretically simple conclusion of Pflüger's essay on *The Art of Prolonging Human Life*—' Avoid the things that are harmful and be moderate in all things '.

Attempts have often been made to correlate the duration of an animal's life with its structural or functional characteristics, and up to a certain point this way of looking at it is useful. For the living creature is a consistent unity, and its length of life must be correlated with its whole being. It is evident that a very large animal will not be a very short-lived animal, but the difficulty is that animals equal in size are often very far from equal in length of life. It is natural that a relatively easy-going animal like a sea-anemone should be able to survive very much longer than an intensely living insect, but the difficulty is that equally active insects may differ greatly in their length of life. In his famous essay *On the Duration of Life* (1881) Weismann considered the various attempts to correlate length of life with size, with intensity of life, with the duration of the growing period, and so on, but found that none of the correlations could be generalized. He was led to the conclusion that length of life, like size, is an *adaptive* character gradually defined in relation to the conditions of life of the species. If a species is endangered in the struggle for existence, and shows a decline of population—too high a death-rate in proportion to its birth-rate—then, seeing that length of life is a very variable quality, the species may be saved by the Natural Selection of the longer-lived variants, who

in virtue of some constitutional toughness survive longer and have more offspring. As Dr. Chalmers Mitchell points out, however, the process might work the other way round by a selection of those variants showing increased reproductivity. If the specific duration of life happened to be a very fixed character, and the fertility very variable, the line of solution might be as Dr. Chalmers Mitchell indicates. Both theories may be right. Unfortunately, neither admits of verification as regards the past.

Death.—In spite of criticisms, we find no good reason against accepting Weismann's doctrine of the immortality of the Protozoa. Truly, these simple organisms do not live a charmed life; they are continually being killed in countless millions; they are sometimes consumed by parasites, and so on; but the point is that some of them at least are not subject to *natural* death in the same degree as higher animals are; that some of them, indeed, may be exempt from natural death altogether. To be devoured by other creatures, to be dried up by the sun, to be killed by a sudden change of temperature, that is the fate of many; but that is *violent* death. Others are occasionally destroyed by internal parasites smaller and simpler than themselves, but that is *microbic* death. To the *natural* death which ensues from the physiological insolvency of the body they are immune. The reasons are to be found in their relative simplicity of structure; they can continuously make good their wear and tear; and in their relatively simple modes of multiplication, which do not involve the nemesis so familiar in higher animals. It is well known that a family of Infusorians all descended from one individual isolated in a basin will often come to an end, one of the reasons being the absence of

any conjugation or primitive pairing; another reason being that the medium is or becomes in some way abnormal. But Weismann's doctrine postulates natural conditions, which would, of course, include the possibility of conjugation, and an ever fresh medium. A recent worker, Mr. G. T. Baitsell, reports that he has discovered an optimum medium in which one of the Infusorians will thrive and multiply indefinitely without conjugation and without introduced tonics.

It is a familiar fact that in the history of a hay infusion, one kind of Protozoon succeeds another, which disappears before it. But this disappearance is sometimes due to violent death, and is sometimes not more than passing into a latent state, as the result of deficient food or accumulated waste-products. And again, it may be admitted that when a Protozoon divides into two or many individuals, there is, in a sense, a disappearance of a particular individuality which went through a particular sequence of experiences; yet we cannot speak of death when one creature directly turns into two or into many, and when there is nothing left to bury.

It is not improbable that very simple multicellular animals, such as the freshwater Hydra, may go on living indefinitely if the natural conditions are altogether propitious. The structure and the multiplication of Hydra are alike so simple, that there seems no good reason why it should die a natural death. But as the body became more complex, death was instituted as a tax on progress. In discussing senescence we have mentioned some of the facts which more or less certainly involve natural death, but they are mostly reducible to two: (1) That the effects of wear and tear in the body are not readily made good with

anything like thoroughness, and (2) that the process of reproduction tends to become physiologically exhausting, especially to the female sex. It is a noteworthy fact, however, that in wild nature, the usual termination of life is violent. Most animals die before their time, devoured by their fellows, killed off by some environmental vicissitude, or starved by a seasonal disappearance of their food. Very few cases of microbic death are known among wild animals, and it is possible that all such cases are due to some human interference. Sir Ray Lankester cites the case of a sandhopper which suffers from a bacterial epidemic, but admits that this may be quite 'unnatural'. In regard to the legions of parasites with which animals are infested, it has to be recognized that these are rarely fatal. It would be almost a contradiction in terms that they should be, for it is not advantageous to a parasite to kill its host. Parasites are destructive when they are transported into hosts which are not physiologically accustomed to them, which have altered their geographical distribution, and thus become susceptible to novel intruders. Then we hear of plagues and decimation, but in most cases parasitism is an old-established, going concern. There rise in the mind cases like those of Ichneumon-flies, which lay their eggs in caterpillars and the like, and there the fatality is well known. The Ichneumon-grubs hatched in the caterpillar, proceed to devour their temporary host. But this is not an ordinary type of parasitism.

On the whole, therefore, we are led to agree with the general conclusion, which many naturalists have reached, that in a state of Nature, most animals die a violent death before they have nearly reached the end of their tether. And this is one of the reasons why life in Nature is so

vigorous and wholesome. As Goethe said, 'Death is her expert device to get plenty of life.'

Summary.—There is, as we have hinted, reason to believe that natural death is not to be regarded simply as an intrinsic necessity—the fate of all life; we can carry the analysis further, and say that it is incident on the complexity of the bodily machinery, which makes complete recuperation wellnigh impossible, and almost forces the organism to accumulate arrears, to go into debt to itself; that it is incident on the limits which are set to the multiplication and renewal of cells within the body, thus nerve-cells in higher animals cannot be added to after an early stage in development; that it is incident on the occurrence of organically expensive modes of reproduction, for reproduction is often the beginning of death. At the same time, it seems difficult to rest satisfied with these and other physiological reasons, and we fall back on the selectionist view that the duration of life has been, in part at least, punctuated from without and in reference to large issues; it has been gradually regulated in adaptation to the welfare of the species.

As we have suggested in *The Biology of the Seasons*, several groups should be distinguished. (1) The first is that of the immortal unicellular animals which never grow old, which seem exempt from natural death. (2) The second is that of many animals which reach the length of their life's tether without any hint of ageing and pass off the scene—or are shoved off—victims of violent death. In many fishes and reptiles, for instance, which are old in years, there is not in their organs or tissues the least hint of age-degeneration. (3) The third is that of the majority of civilized human beings, some domesticated and some wild

animals, in which the decline of life is marked by normal *senescence.* (4) The fourth is that of many human beings, not a few domesticated animals, e.g. horse, dog, cat, and some semi-domesticated animals, notably bees, in which the close of life is marked by distinctively pathological *senility.* It seems certain that wild animals rarely exhibit more than a slight senescence, while man often exhibits a bathos of senility. What is the reason of this ?

The majority of wild animals seem to die a violent death, before there is time for senescence, much less senility. The character of old age depends upon the nature of the physiological bad debts, some of which are more unnatural than others, much more unnatural in tamed than in wild animals, much more unnatural in man than in animals. Furthermore, civilized Man, sheltered from the extreme physical forms of the struggle for existence, can live for a long time with a very defective hereditary constitution, which may end in a period of very undesirable senility. Man is very deficient in the resting instinct, and seldom takes much thought about resting habits. In many cases, too, there has come about in human societies a system of protective agencies which allow the weak to survive through a period of prolonged senility. We cannot, perhaps, do otherwise ; but it is plain that to heighten the standard of vitality is an ideal more justifiable biologically than that of merely prolonging existence. For if old age be then permitted, it is more likely to be without senility. Those whom the gods love die young.

In Illustration

Freshwater Sponge.—Some of the simplest animals or Protozoa have very complex life-histories, especially

in some of the parasitic forms; but they are too difficult for discussion here. As a first illustration, therefore, we take a multicellular animal, the freshwater sponge. In some of the freshwater sponges—which form the family Spongillidæ, aberrant in having left the sea—an interesting alternation of generations has been described by W. Marshall and others. In autumn the sponge, which grows on sticks and stones in the river or lake, suffers from the cold and from a scarcity of food. It begins to die. Throughout the moribund body, however, little companies of cells group themselves together and become surrounded by a protective capsule of tightly-fitting, somewhat capstan-like, flinty spicules. Each group is called a gemmule, and while the parent dies, the gemmules survive the winter. In April or May they float away from the debris of the old body, and develop into new sponges. Some become short-lived males, others more stable females. The ova produced by the latter and fertilized by spermatozoa from the former, develop into a summer generation of asexual sponges, which, in turn, die away in autumn, and give rise to gemmules. The formation of gemmules is an asexual mode of multiplication, and it also secures dispersal, for the gemmules can be swept about by currents without being damaged, until eventually they effect lodgment in some crevice and begin to develop.

Zoophytes and Swimming Bells.—Many of the graceful colonies of Hydroid polyps, often called Zoophytes, liberate in the summer months transparent reproductive buds specialized for free-swimming. These Medusoids, which are in a very general way like miniature jelly-fishes or Medusæ, swim in the open water by contractions and expansions of their bells. They are sexual stages in the

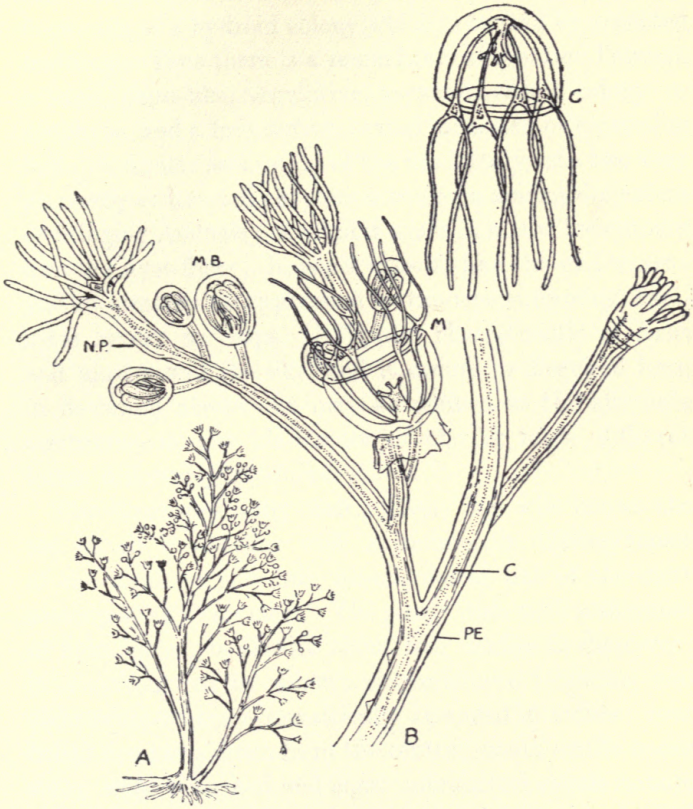
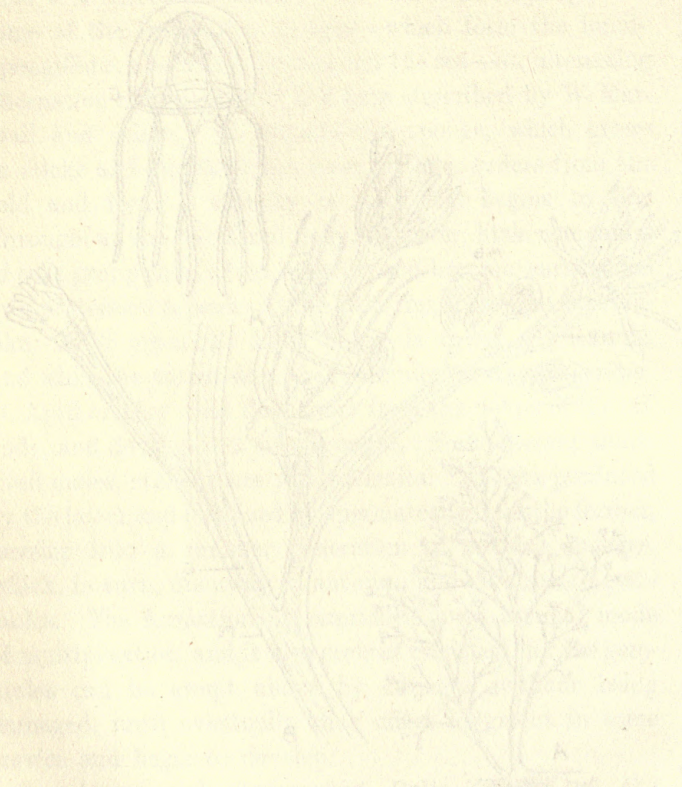


FIG. 68.—Life History of a Hydrozoon, Bougainvillia fruticosa. A. The zoophyte colony, natural size. B. A portion enlarged, showing PE, protective perisarc; C. The living connexion between the polyps; NP. a nutritive polyp, MB. a medusoid bud, M. a medusoid about to be liberated. C. A free-swimming sexual medusoid. (*After* Allman.)



life-history, and produce ova and spermatozoa. The fertilized ova develop into free-swimming embryos, which soon settle down and become polyps. Each polyp is the beginning of a hydroid colony which is formed by repeated budding. Thus there is a remarkable alternation between a fixed, plant-like, vegetative, asexual hydroid colony or zoophyte, and a free, active, sexual medusoid or swimming bell. A similar separation of the life-history into two very markedly contrasted chapters is common among Cœlentera or Stinging Animals; we find it again in many Trematodes like the liver-fluke; in some insects, like the gall-wasps; and in remarkable expression in the free-swimming Tunicates known as Salps. It is also characteristic of ferns and mosses and the like, and it occurs in disguised form in flowering plants. It may be defined as the alternate occurrence in one life-history of two or more different forms differently produced.

The Common Jelly-fish.—Every one who knows the sea at all is familiar with swimming or drifting shoals of the common jelly-fish, *Aurelia aurita*, one of the most cosmopolitan of animals. The glassy disc, with a shimmer of light violet, is usually about four inches in diameter; it is surrounded by minute circumference tentacles, and eight sense-organs symmetrically arranged in niches; four frilled lips hang down from the central mouth on the under side; eight branched and eight unbranched canals radiate out from the central stomach to a peripheral canal; and there are four conspicuously coloured male or female reproductive organs. The fertilized eggs develop into minute free-swimming oval larvæ, which after a short period of activity settle down on a stone or seaweed. They develop into little polyp-like forms, known as 'Hydra

tubæ,' about an eighth of an inch in height, with a mouth, gullet, and tentacles. In ordinary conditions this sedentary stage grows larger, and displays a series of transverse annular constrictions, becoming like a miniature pile of saucers—the strobila stage. Each disc or saucer is separated off in turn as a free-swimming young jelly-fish (or Ephyra), which feeds on microscopic organisms, grows rapidly, undergoes certain structural changes, and becomes a sexual jelly-fish. Thus we find that a characteristically free and active animal, the jelly-fish, includes in its life-history a fixed and vegetative polyp-stage—alternation of generations again (see Fig. 72).

FIG. 69.—Minute transparent free-swimming larva of a sea-cucumber or Holothurian, showing transverse bands of cilia (C) and peculiar protruding 'arms' (A).

Echinoderms. — The newly-hatched larvæ of sea-urchins, sea-cucumbers, starfishes, and brittle stars are diffusely ciliated two-layered thimble-like sacs—in fact, not very remarkable gastrulæ. But they soon become quaintly transformed by the outgrowth of processes and the formation of special bands of cilia into extraordinarily shaped larvæ, adapted for open sea life. In sea-urchins, for instance, the quaint larva, known as a Pluteus, is often

FIG. 70. — Minute transparent free-swimming larva of a sea-cucumber or Holothurian, showing peculiar protruding 'arms' (A) and calcareous plates (CP).

compared to a microscopic six-legged easel, and the same type occurs in Brittle-stars. Those of starfishes and sea-cucumbers baffle brief description. Those of feather-stars or Crinoids are not so divergent.

But even more remarkable than the shape of the larvæ is the fact that they do not develop directly into the adult, in the way in which a tadpole develops into a frog. The development is circuitous. Within the larva a new formation begins, on a fresh architectural plan, utilizing some parts and rejecting others, and the result is the adult form (Fig. 21). The curious arms or processes characteristic of the larva are in part absorbed and in part thrown off. The wandering amœboid cells which play so diverse and important a rôle in the animal kingdom are very active, at once as sappers and miners in breaking down, and as builders in the re-construction.

Mermis and Horse-hair Worms.—A curious sight is sometimes seen in gardens, especially after heavy rains in summer—a thin thread of a worm raising itself into the air from the top of a cabbage plant and writhing as if in search of something. That is a female Mermis, and it is supposed to be seeking out a place for egg-laying more suitable than the very damp earth. This is an episode in a curious life-history. The mature Mermithidæ live in the earth or in fresh water, and so do the first larval stages. From the earth or water, the young larvæ migrate and bore actively into beetles, caterpillars, millipedes, slugs, and so on. When they become mature, the worms leave their hosts. Now it is noteworthy that no food is taken either by the adults or by the young larvæ. All the feeding is done by the second larval forms during the parasitic period. Many adult insects are non-nutritive

and wholly reproductive, using the energy accumulated in the larval period; but in the Mermithidæ the state of affairs is even more striking, for the energy accumulated in the second larval stage serves not only for mature life and for reproduction, but also for the first chapter in the life of the next generation! The black horse-hair worms, hundreds of which are sometimes seen in a little wayside pool, each about the thickness of a hair from a horse's tail, have a somewhat similar life-history. The minute larvæ enter water-beetles and other insects and grow large within them, to a length of four inches or so, much longer indeed than their hosts. When they become mature they work their way out of the insects and sometimes suddenly appear in large numbers in the pools. We have seen a pool a couple of feet across, so crowded with them that over a hundred could be lifted in a handful, just like a bunch of vitalized hairs, as the mediæval naturalists believed them to be.

Barnacles and Acorn-Shells.—The barnacles (Lepas, etc.) on floating timber and the acorn-shells (Balanus) encrusting the shore rocks are much alike in their life-history, and a very remarkable one it is. Out of the egg of the barnacle there emerges a minute free-swimming larva—a Nauplius—with three pairs of appendages, an unpaired eye and a delicate dorsal shield. After moulting several times, it fixes itself by means of its first pair of feelers, which have become suctorial, to some floating object, and secures its adhesion by a secretion of gluey material. The anterior end by which it has fixed itself is drawn out into a long flexible stalk, and a thorough-going change occurs in the bodily structure, until the final form is reached. During this metamorphosis the animal

fasts, living on its stores. Out of the egg of the Balanus a nauplius larva likewise emerges. It feeds and grows and moults, and acquires a firmer dorsal shield, a longer

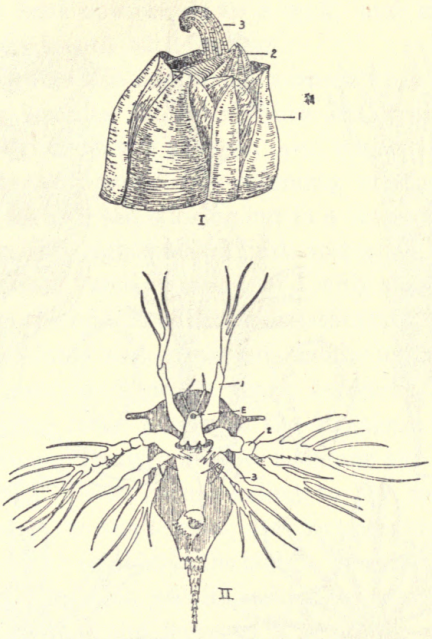


FIG. 71.—I. An acorn-shell (Balanus), showing: 1, the external rampart of calcareous plates; 2, the valves which shut in over the retracted body; 3, some of the thoracic appendages protruded. II. The free-swimming larva of the same, known as a nauplius: 1, 2, 3, first three pairs of limbs, corresponding to the antennules, antennæ, and mandibles of the adult. It is almost microscopic.

spined tail, and stronger appendages. It then changes into a somewhat 'water-flea'-like form—the Cyprid stage—with two lateral eyes, six pairs of swimming appendages, a bivalve shell, and so on. It is very active, but it

does not feed, so that not unnaturally it soon comes to rest as if in fatigue. It fixes itself head downwards on the rock or shell by means of its first pair of feelers and some glutinous cement. It loses its bivalve shell and makes

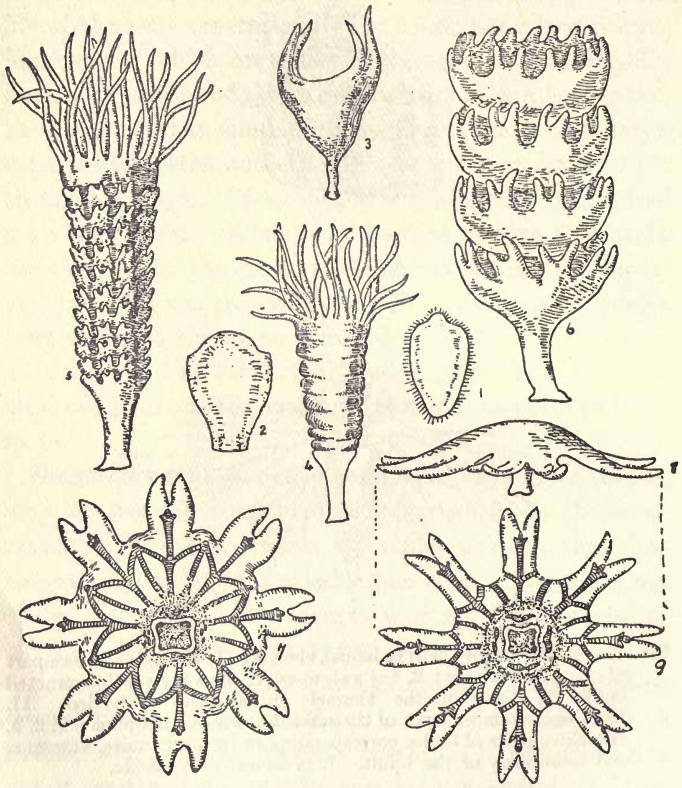


Fig. 72.—Life-history of the common jelly-fish, Aurelia aurita. (*After* Bronn.) 1, the free-swimming ciliated planula ; 2, the same fixed ; 3, the hydra-tuba, with four tentacles ; 4 and 5, the strobila or pile-of-saucers stage ; 6, a later stage after most of the discs have been separated off ; 7, a separated off disc or ephyra, showing 8 bifid processes each with a sense-organ ; 8–9, the ephyra seen from the side and from beneath. The mouth is shown in the centre.

another of a different pattern; it undergoes a metamorphosis, fasting all the time, and becomes a miniature adult with its beautifully waving curl-like appendages—comparable, as Huxley said, to a shrimp fixed head downwards and back downwards to a rock, and kicking its food into its mouth with its legs.

Shore Crab.—No one could suspect from an observation of a common shore-crab, such as *Carcinus mœnas*, that its early youth was spent in open waters. The larva is a minute transparent free-swimming creature, known as a zoæa, with its tail sticking out in a line with the rest of the body, with eight pairs of limbs instead of the adult's total of at least twice as many, and with a curved spine arising from the middle of the cephalothorax shield. This little animal feeds and grows and moults its cuticle, and feeds and grows and moults again, becoming eventually a second larval form, known as the Megalops. This has lost the spine and gained a broader body and also additional limbs, namely those corresponding to the forceps and walking legs of the adult crab. But its tail is still sticking out in a line with the rest of the body. The Megalops feeds and grows and moults, gets its tail tucked forwards under the cephalothorax, and becomes a miniature crab about the size of a quarter of one's little finger nail—a creature no longer suited for free swimming, but for the floor of the sea in shallow water, whence it creeps up on to the shore.

Freshwater Insects.—There is something peculiarly fascinating in the life-histories of freshwater insects, partly because of the sharp contrast between the aquatic and the aerial chapters, partly because of the subtlety of the adaptations to life in the water. Every one has enjoyed

Tennyson's picture, which is only one out of a possible score equally dramatic.

> To-day I saw the dragon-fly
> Come from the wells where he did lie.
> An inner impulse rent the veil
> Of his old husk: from head to tail
> Came out clear plates of sapphire mail.
> He dried his wings; like gauze they grew;
> Thro' crofts and pastures wet with dew
> A living flash of light he flew.

May-Flies.—Not unfamiliar in May or June is the emergence of a crowd of May-Flies or Ephemerides from the pond or from a backwater of the river. In our *Biology of the Seasons* we have described the long larval life in the water, sometimes lasting for two or three years; the growth and the moultings; the final moult, the unfolding of the filmy wings, and the transient aerial dance sometimes lasting only for a day. The long-drawn-out nutritive and growing period stands in remarkable contrast to the hurried reproductive chapter. They rise like a living mist from the pond; they dance in the pleasant light of the summer evening; they dimple the smooth water into smiling with a touch, chasing, embracing, separating. . . . 'They never pause to eat—they could not an they would; hunger is past, love is present, and in the near future is death. The evening shadows grow longer—shadows of death to the day-flies. The trout jump at them, a few rain-drops help to thin the throng, the stream bears others away. The mothers lay their eggs in the water and wearily die forthwith, cradle and tomb are side by side; and the males also pass from the climax of love to the other crisis of dying. But after all, the eggs are in the water, the

promise of the future; the individuals perish, but the race lives on.'

Gnats.—Early in spring we may find the gnats' boat of 300 eggs moored to the water-weed. Early in May the larvæ abound in the pools, quaint, dark-coloured creatures, about half an inch long, with slender bristly bodies, and mouth-parts which waft in food-particles.

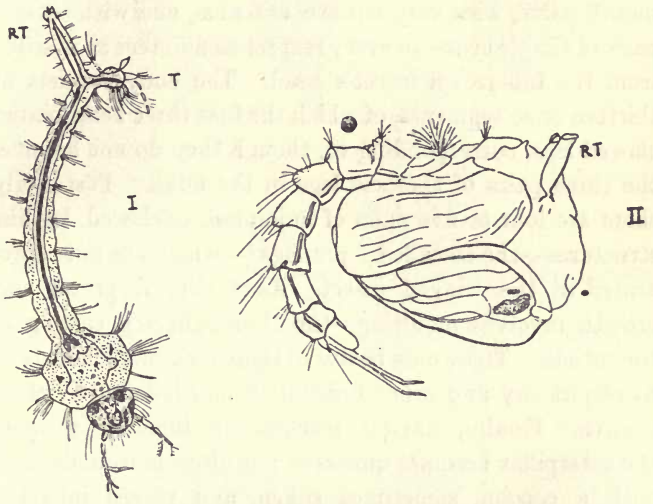


FIG. 73.—I, Larva. II. Pupa of the Gnat (Culex pipiens). (*After* Hurst.) RT, respiratory tubes. T, tail end of larva.

They seem to spend their day between the bottom of the pool and the surface-film, which they perforate with a terminal valved breathing organ at the end of the tail. Hanging head downwards, they accumulate air enough to serve during prolonged submergence. They grow apace and moult three times without changing much in their character. But at the fourth moult a pupa emerges, light-

brown in colour, with a large head and a small body, with anterior breathing tubes, and no open mouth. After a few days the pupa husk splits and the winged gnat escapes.

Other Insects.—No life-history is more marvellous than that of a moth or butterfly. Out of the egg, after a very remarkable development, there emerges a minute worm-like caterpillar, usually active, voracious, and of rapid growth. Typically, it shows a hard head with biting mouth-parts, with very minute antennæ, and with several pairs of simple eyes—in every respect as different as possible from the full-grown insect's head. The body consists of thirteen or so segments, of which the first three bear jointed clawed legs, corresponding to, though they do not become, the three pairs of thoracic legs in the adult. Posteriorly there are four or five pairs of unjointed, unclawed, leg-like structures—the so-called 'pro-legs'—which are not represented in the winged insect. As it eats it grows, and growth involves moulting—the thoroughgoing casting of the cuticle. There may be five of these moults, each marked by respiratory and other difficulties, and followed by rapid growth. Finally, having reached its limit of growth, the caterpillar becomes quiescent; it often surrounds itself with a cocoon, sometimes silken, and passes into the chrysalis or pupa state. Serious respiratory and other difficulties beset the pupa; a process analogous to inflammation pervades it; the old structure is broken down and groups of formative cells of an embryonic character proceed to build up the adult body on a new architectural plan. Everything is changed—mouth-parts, antennæ, food-canal, muscles, everything. New structures, such as wings and compound eyes, make their appearance. By and by there struggles painfully out of the imprisoning husk an

I
II
III
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V

entirely new creature, the fully-formed moth or butterfly. Two big facts stand out. The first is that the life-history is divided into a feeding growing period and a fasting reproductive period. For the amount that adult Lepidoptera eat is trivial, and some have mouths that do not open. In no case among the higher insects is there any growth after the adult form is attained. The other big fact is the zig-zagness of the development. It proceeds for a time along a certain path; it comes to a standstill; it turns back on itself; and then it goes ahead once more on a quite different line.

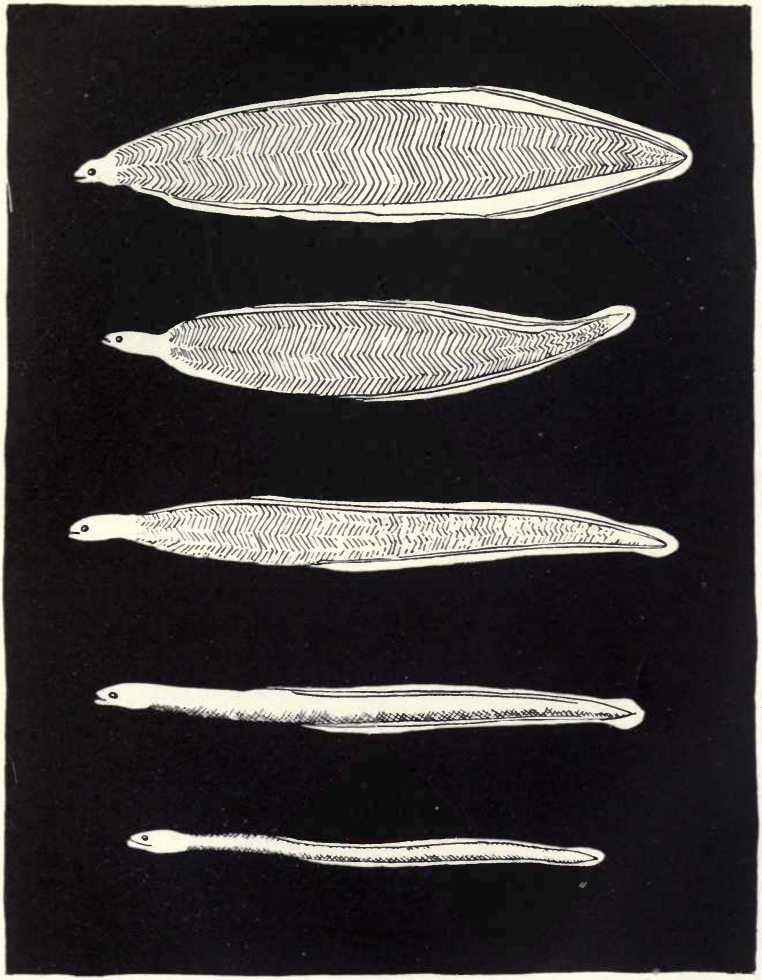
Fabre has told us many stories in regard to the life and habits of the large plant-bug, called Cigale, famous for its instrumental music and infamous for the Parthian shot of noxious stuff which it delivers on our face as it flies away. The old legend had it that the Cigale who sang in the summer was forced to borrow from the ant when the scarcity of winter came, but the facts are the other way round. When all the world is thirsty in the midsummer drought, the Cigale with its delicate auger broaches the cask of a suitable shrub. 'Plunging her proboscis into the bung-hole, she drinks deliciously, motionless, and wrapt in meditation, abandoned to the charms of syrup and of song'. Many thirsty insects draw to the well, and the aggressive ants, by sheer force of numbers and impudence, succeed in hustling the Cigale away. They then make the most of what is left of sweet sap.

The eggs of the Cigale are laid about July, in batches in dry twigs, ten or so in each of thirty to forty chambers. In autumn a remarkable *primary larva* emerges, which Fabre compared to a very minute fish with one fin—the first two legs being joined to form the only movable

appendage. This quaint form moults and there comes forth a migratory larva, no bigger than a flea, which hangs by its tail for an hour or a day at the end of a thread, waving its antennæ and bending its legs. It falls to the ground and seeks for a spot of pervious soil into which to burrow. It becomes a deep burrower and taps the roots of plants, probably remaining, Fabre thinks, for four years underground. We venture to quote from his *Social Life in the Insect World*, the summing up of this extraordinary life-history.

'Four years of hard labour underground, and a month of feasting in the sun; such is the life of the Cigale. Do not let us again reproach the adult insect with his triumphant delirium. For four years, in the darkness, he has worn a dirty parchment overall; for four years he has mined the soil with his talons, and now the mud-stained sapper is suddenly clad in the finest raiment, and provided with wings that rival the bird's; moreover, he is drunken with heat and flooded with light, the supreme terrestrial joy. His cymbals will never suffice to celebrate such felicity, so well earned although so ephemeral'.

The common house-fly (*Musca domestica*) can pass through the whole of its intricate development—with three larval stages and a pupal stage—in eight days, if the temperature is steady and high (35° C.), but the same process may be lengthened out over several weeks. According to Hewitt, the flies become sexually mature in 10–14 days after their emergence from the pupa-stage. Each fly lays from 120–150 eggs in a single batch, and may lay as many as six batches during its short life. Except in warm stables and the like, where reproduction may go on practically without stopping, the breeding period is usually from June to October.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There is a rather famous Aphis—*Schlechtendalia chinensis* —which makes galls on *Rhus semi-alata* in Japan and China. The galls are used in dyeing and tanning—they are rich in tannin, and in former times they served the Japanese women as a tooth-powder for blackening their teeth. Sasaki has almost cleared up its complicated life-history. There is a succession of wingless females, parthenogenetic and viviparous, and after a time winged females appear which lay eggs containing well-advanced embryos. These develop into wingless females again. No males have been found, and we have a glimpse of a possible continuous Parthenopeia.

Sometimes the life-cycle is long drawn out, as in the case of the seventeen-year cicadas (*Tibicina septendecim*), well known in the United States, where they are often called 'locusts'. (A small British relative, *Cicadetta montana*, is sometimes found in the New Forest.) The peculiarity of the Cicada is that it is specially abundant every seventeenth year in the northern States, or every thirteenth year in the southern States. The eggs are laid on the twigs of trees; the larvæ drop to the ground and cluster on the roots, sucking the sap; after a prolonged larval period, there is short pupation, and a broad, black insect, with reddish nervures on its wings, emerges. The loud instrumental music or stridulation made by the males is very familiar.

Tunicates.—The majority of Tunicates, belonging to the Ascidian type, are somewhat nondescript marine animals, of sedentary habit, often compared to wine-skins or leather water-bottles. Until their development was made known, no one suspected that their relationships were with backboned animals. The egg develops into a

minute transparent free-swimming larva, suggestive of a tadpole. For some hours it enjoys a free-swimming life, propelling itself by means of its tail. At this stage it has a brain and a delicate dorsal nerve-cord, a supporting dorsal axis (or notochord) in its tail, a brain-eye, a ventral tubular heart, and two or more pharyngeal gill-slits—all of them distinctively vertebrate characters. But it does not fulfil the promise of its youth! It soon gives up its active life, fastens itself by its head to seaweed or stone, and almost immediately falls victim to rapid degeneration. The nerve-cord is lost and the brain-eye; the tail shrinks and disappears, devoured by its own phagocytes; the posterior part of the body becomes twisted dorsally through 180°—and within a few hours the creature begins to look like a miniature Ascidian—one of the most signal instances of individual degeneration in the whole animal kingdom.

Eels.—There is a fascination in the life-history of the freshwater eel, though the mystery has been in part removed. From inland ponds and quiet stretches of rivers the full-grown eels migrate on autumn nights seawards; they pass out to sea into deep water, and probably die after reproduction, for they never return. Obscurity still hangs over the deposition and fertilization of the eggs and over the early stages of development. The transparent Leptocephalus larvæ are found near the surface, and are for a year or more pelagic. From the open sea, the young eels, when they have become cylindrical in shape, migrate shorewards and pass up the streams in a marvellous procession or eel-fare.

On the *Michael Sars* (1910) expedition, the larvae of the common eel were found not only on the Continental slopes, but also in mid-ocean over the greatest depths, both over

the deep eastern and western basins and over the Azores ridge separating them. The larger larvæ were all got north of the Azores, and the younger stages were all found south of the Azores, which led Dr. Hjort to suggest that the spawning area is probably in the southern central part of the North Atlantic. No transformation-stages were found in mid-ocean, and it may be that the change only occurs on the Continental slope. But it must always be remembered that the developing eggs have not yet been discovered.

The Salmon.—In British rivers, the time of salmon spawning is in the late autumn or winter. The eggs are laid in the gravelly bed of the stream, and they develop very slowly. After three or four months the egg-envelope bursts and the larva is set free, still encumbered with a large yolk-sac, on the contents of which it subsists for about seven weeks. About the eighth week after hatching, the supply of yolk is exhausted, and the 'fry'—about an inch long—begin to fend for themselves and to move energetically. They grow by the end of the year to be somewhat trout-like 'parr', about four inches long. In their second year, usually, the young salmon change in coloration, donning a beautiful 'sea-jacket,' and are known as 'smolts'—six or seven inches in length. These go down to the sea, feed voraciously, grow rapidly, accumulate stores, and become grilse. After a variable period of feeding and growing, which may last a year or two years or more, they are ready to spawn, and return to the place of their birth in the fresh waters. Such in outline is the typical life-history of the salmon, but there are many variations on this theme. We have described in our *Biology of the Seasons* the journey up the rivers, the struggle against the stream

and the leaping of the falls—all implying efforts which are the more remarkable since there seems to be no evidence that the adult salmon ever feeds in fresh water. Few salmon seem to spawn more than once, and some die of spawning. It is of interest to contrast the eel and the salmon, for the former is a marine fish which has taken secondarily to a life in the rivers and ponds, while the latter is primarily a freshwater fish which has taken to the exploitation of the sea.

In the case of the Pacific salmon (*Oncorhynchus*) the general facts are the same, but a simplification is implied in the fact that the adults die after spawning once. They do not return to the sea. The run up the rivers to the spawning grounds several hundred miles off is very remarkable; it may occupy two or three months; after tidal waters are passed the fish continues, according to Professor C. W. Greene's 'marking' experiments, at an average speed of not less than 7½ miles a day; all the work is done on an empty stomach, for feeding stops absolutely in fresh water; the work often includes jumping six or seven feet in height and then continuing against a swift rush of water; and all the time the reproductive organs are growing rapidly at the expense of other parts of the body. It is a remarkable performance.

Frogs.—Out of the frog's egg, in the midst of its enveloping sphere of jelly, there emerges a ciliated larva, which has already had an embryonic development of about a fortnight. It is mouthless and limbless; the eyes growing out from the brain have not yet reached the surface; there are the beginnings of external gills; and there is a glandular cement organ on the under surface of the head, by means of which the larva attaches itself to water-weed and other

objects. The gills become branched; the mouth opens; the food-canal lengthens till it is like a watch-spring; four gill-clefts open from the pharynx to the exterior; the larvæ feed greedily on vegetable matter, and grow rapidly; as their power of locomotion increases, the cement organs dwindle.

The true tadpole stage then begins. A skin-fold covers the gills, which are absorbed, only, however, to be replaced by a second very similar set. Both sets are comparable to the external gills of the double-breathing lung-fishes (or Dipnoi) rather than to the gills of ordinary fishes. The mouth acquires horny jaws and the fleshy lips bear horny papillæ. A gill-chamber is formed on each side, with one exhalant opening, however, to the left. The circulation is like that of a fish, and the heart is two-chambered; the tadpole is about a month old. The third period is marked by the appearance of the limbs and by the development of the lungs. The tadpoles come to the surface to take gulps of air; the circulation ceases to be piscine; the heart becomes three-chambered; the tadpole is two months old.

The tadpole reaches its full size, and the metamorphosis is close at hand. It seems to fast, but the tail, which undergoes internal dissolution, furnishes, through the medium of the amœboid phagocytes, some nourishment to other parts of the body. The horny jaws are lost; the frilled lips shrink; the hitherto rounded mouth becomes frog-like; the tongue enlarges and gains mobility; the eyes are exposed; the fore-limbs, which have been kept back by the gill-cover, become free. The animal recovers its appetite, becomes thoroughly carnivorous, gets a relatively shorter intestine, has its hind legs relatively lengthened, and, having

lost all trace of its tail, hops ashore a little frog—about three months old.

It is very interesting to observe that in this single life-history there is first of all nutritive dependence on the legacy of yolk, then a period of vegetarian diet, then a somewhat omnivorous period, then a fast, then a carnivorous time, and finally an insectivorous adult life. Similarly, as regards respiration, there is great variety. The newly-

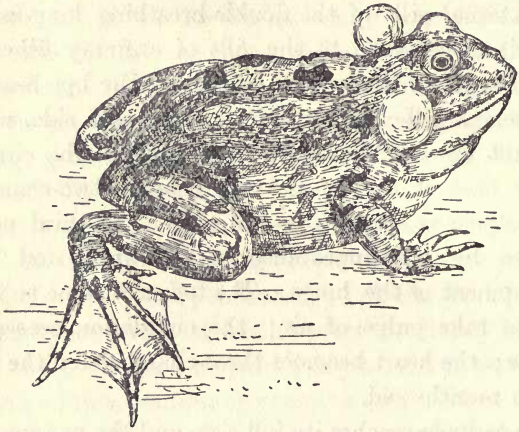

Fig. 76.—Male Edible Frog, Rana esculenta, showing the resonating sacs protruded from the corners of the mouth. From a specimen.

hatched larva breathes through its skin; it has a first set of gills; it develops gill-clefts; a second set of gills arising under the gill-covering replaces the first set; when it is two months old it breathes by both gills and lungs; the gills disappear and the frogling is a lung-breather; but all through the winter the frog harks back to the primitive cutaneous respiration.

As regards recapitulation, it goes without saying that

the larval frog is never like a young fish. It has no scales, for instance, nor fin-rays supporting the tail-fin, and there are much more fundamental differences. It is an Amphibian from first to last. And yet, if we fix our attention on the development of the heart or the circulation, we must admit that the tadpole passes through stages which are permanent in fishes. In other parts of its organogenesis it climbs up its own genealogical tree, and to this extent at least confirms the 'Recapitulation Doctrine'.

It is very instructive to compare the long drawn out life-history of the common frog with that of some of its relatives. In the Surinam toad (Pipa) and in some Tree-Frogs, the tadpole stage is skipped altogether, while in the Paradoxical Frog (*Pseudis paradoxa*) the tadpole stage is much more impressive, at any rate, than the adult. In his delightful *Infancy of Animals*, Mr. W. P. Pycraft tells us that the tadpole is nearly a foot long, nine inches going to the enormous tail, and three inches to the head and trunk. During a prolonged fast, and after no little re-modelling, this huge larva is shaped into an adult frog, only two and a half inches in length.

Retrospect.—The general idea which these life-histories suggest, is that the various chapters of a typical life-history are capable of being lengthened out or shortened down according to the conditions of life; and to some extent, also, that particular conditions of life, may have been sought out to suit particular forms of the life-curve. The various arcs on the span of life are, so to speak, elastic. The line of life is like a telescope with many joints; it can be drawn out to its full length; it can be pushed in to a minimum; or one part can be lengthened and another shortened. Just as some flowers remain, as it were, per-

manent buds, so some animals remain always young. In what is called pædogenesis, sometimes illustrated by the Axolotl, even the reproduction is shunted back into larval life, so that adult life is reduced to *nil*. In other cases, the conditions of adult life are extremely riskful, and its duration is contracted to a few weeks or days or even hours! In other cases, it is the larval life that is condensed; thus in the freshwater crayfish, what comes out of the egg is practically a miniature adult; all the usual larval stages, so characteristic of higher crustaceans, have been telescoped into the embryonic development within the egg. Or it may be that the larval life is drawn out for years. The idea should be linked on to what has been noted in regard to the successive chapters in the routine of parental behaviour (see p. 430). It is, in a word, the idea of *temporal* variations, that the life-histories of animals are like tunes, which may be much altered by playing one part out of all proportion slowly, and another part very quickly. We may even go further, and recognize that there are youthful types of organisms and others which are born old. But this is the beginning of another story.

The Story of Niners.—A score of miles, as the crow flies, from the sea, there is a stretch of slowly-flowing river, from which a mill-race has borrowed most of the water. There are many pools with sand or mud, and if this be stirred, we get a glimpse of curious, sluggish, eel-like creatures, variously known as niners, or prides, or larval lampreys. Some four to six inches long at the end of their fluviatile life, with a polished dark skin, with a horse-shoe lip around a toothless mouth, they are jawless, limbless, and scaleless, and therefore cannot be ranked as fishes. Although they are called 'niners', i.e. nine-eyes (German,

Neunaugen), they are blind; for their eyes, growing out from the brain as vertebrate eyes always do, have not yet reached the surface. There are seven gill-slits on each side, and these have been popularly counted in as eyes. These curious old-world creatures are often regarded as the young of eels, but, as a matter of fact, they are far below the level of fishes on the genealogical tree of animals. Whence have they come and what future is before them?

The Sea Lamprey (*Petromyzon marinus*), whose larvæ the niners are, is a strong muscular animal, sometimes a yard long, abundant in the Mediterranean and the North Atlantic. It also occurs in the American lakes, having in this case dispensed with its normal journey to the sea. The colour is greyish green with darker spots. The structural peculiarities are numerous. For apart from the absence of jaws, limbs, and scales, which we have already mentioned, there is a circular adhesive disc around the mouth and lined with rows of horny teeth, there is a very muscular protrusible 'tongue' bearing horny plates for rasping with, there is an unpaired nostril far back on the top of the head, like a porpoise's blow-hole, and there are curious gill-purses. Their habits are not less remarkable. They attach themselves to living fishes and rasp the flesh and suck the blood. They take a very firm hold of their victims and make deep holes, and they are sometimes carried for long distances by large fishes, such as salmon. They migrate in spring or early summer from the sea (or the lakes of the State of New York) to the rivers, usually changing to a more yellowish colour; they make nests of stones, and they die after spawning.

It is a very general fact of Natural History that when the habitats of adult and young are different, the cradle-

area represents the old home. The salmon is essentially a freshwater fish, though its nutritive periods are mostly spent in the sea. Its spawning in the rivers is indicative of its original home. The common eel, on the other hand, which has its nutritive period in the fresh waters, goes down to the Deep Sea to spawn, and is probably to be regarded as essentially a marine fish with its old home in the greater depths. A similar argument leads to the view that the Sea-Lamprey is primarily a freshwater fish which has secondarily taken to spending a nutritive period in the sea. We have already spoken of the forms of *Petromyzon marinus* in lakes of the State of New York, which do not leave the fresh water at all, though they migrate from lake to river to spawn. In the case of the River Lampern (*Lampetra fluviatilis*), whose young are also called 'niners', some remain all their lives in fresh water, while others go down to the sea. This is paralleled by the Trout (*Salmo trutta*), some forms of which remain in lakes and rivers, while others (distinguished *nominally* as Sea-trout) go down to the sea. It must also be noted that a number of species of lamprey, such as the Brook Lamprey, never leave the fresh water, and this may be taken as another argument in support of the view that the Sea Lamprey is secondarily marine. Let us follow them now on their return journey to their cradle-area.

The spawning of the Sea Lamprey has been well described by Dr. L. Hussakof. A circular depression is made, two to three feet in diameter, in the river-bed. Large numbers of pebbles and stones are carried out of the chosen area until a shallow basin is formed, naturally with a floor of sand and fine gravel. The adhesive disc around the mouth acts like a vacuum-sucker, and it can be made to 'work'

after the animal is dead. Both sexes work at the nest-making, and the males sometimes make considerable preparations before the females arrive on the scene. Sometimes two lampreys will unite their energies in lifting a heavy stone.

When the nest is ready, or while it is being prepared, the female lamprey lays her eggs within the circle, clinging as she does so to a large stone. At the same time the male seizes her by the top of the head, and the two bodies are very rapidly vibrated for two or three seconds, during which the milt or seminal fluid is shed upon the eggs. Fertilization is external. The same remarks might be made in regard to the brook-lampreys—*Lampetra planeri* in Europe and *Lampetra wilderi* in North America. 'The females,' according to Forbes and Richardson, 'spawn in shallow water, and, as a rule, where there is some current over pebbly or stony bottom near the headwaters of a stream. During the spawning process the females cling with their oval mouths to pebbles or stones, and are clasped at the nape by the suctorial discs of the males'. In the case of the river lamprey, a good many couples combine to make the nest and use it in common. The surface of the eggs is covered with an adhesive stuff, to which sand grains adhere, so that the eggs sink. Moreover, they say that the two parents proceed at once to loosen some stones at the upstream side of the nest, so that the loosened sand buries the eggs. There may be several spawnings at short intervals, and then the parents pass down stream to die. For that is the most remarkable fact in the story of the lampreys, that the one generation comes to an end in giving the next generation a beginning. Reproduction is often the beginning of death, but here the end comes quickly.

We are familiar with this in some lower animals, such as May-flies and butterflies, and in some still lower animals, such as some of the worms, but it is rather startling to find a big muscular sea lamprey—a yard long and as thick as a lady's wrist—dead and stranded in the shallow water of the river not far below the spawning-place. What does it all mean? Uprooting and transporting the stones has involved no small expenditure of energy, no little wear and tear; the skin is often bruised and cut (and there are wounds of combat and of mating besides); Bacteria and Fungi begin to settle down (to which the skin of the larva seems to be immune because of a ferment it possesses); the creatures become blind and emaciated, and are often attacked by other lampreys. But all the external causes added up will not account for the wiping out of the adult lampreys after spawning. Every one agrees that these are contributory or accessory, but not the essential causes of death.

A deeper answer is to be found in the fundamental antithesis between nutrition and reproduction. These sexually mature lampreys have not been feeding at all: their hunger has been devoured by love. Profound bodily changes have been associated with the reproductive function, similar to those more familiar in the case of the salmon. The intestine, for instance, is quite out of gear. Deeper still, perhaps, it is possible to go, for it seems legitimate to suppose that the length of life's tether is, in many cases at least, *adaptive*. Where reproduction takes such a grip of the constitution, it would not be well for the race that there should be survival. In other words, those of a type that tended to live longer, but with enfeebled energies, have been eliminated in the course of Natural Selection.

But let us return to the fertilized eggs. They develop quickly and hatch in about a fortnight. About a month later, when about half an inch long, the larvæ leave the nest and seek out quiet stretches of the river. They differ from the adults in the horseshoe shape of the lips, in having a sieve of barbels guarding the true mouth, in the details of their respiratory system, in having much less developed unpaired fins, and in being blind. They form burrows in the sand or mud, and feed on small aquatic animals. It is very difficult for ordinary eyes to see any difference between the larvæ of the various species, and the technical name *Ammocœtes branchialis* is applied to them all.

After three or four years of a somewhat monotonous juvenile life, the larvæ begin to grow up. They put away their larval characters and pass through a metamorphosis, just as a tadpole does in turning into a frog. This is accomplished in the autumn months between the end of August and mid-October. The horseshoe lips are changed into a circle, the barbels into papillæ, the suctorial disc is formed, the teeth develop, internal adjustments are effected, the creatures become more active, and pass down the rivers to the sea or the great lake, where they become strictly fish-eaters. After two or three years of vigorous life and rapid growth the young lampreys have quite grown up, and they return up the streams to their old cradle-area, which is also the place of their death.

A Strasburg fisherman called Baldner is said to have convinced himself more than two hundred years ago that 'niners' grew into lampreys, but his correct conclusion was not accepted till 1826, when A. Müller observed the whole life-history of the brook lamprey—the eggs developing into niners, and these changing into the adult forms.

The lampreys have many primitive features, e.g. in their vertebral axis, their skull, their nasal passage, and they are without doubt very old-fashioned types. They probably diverged from the vertebrate stock before the evolution of definite jaws, but it is *possible* that they long ago lost the jaws which their remote ancestors had. Consistent with their old-fashioned character is the poorly-developed brain, and the low order of intelligence that they exhibit. Bashford Dean and F. B. Sumner have noticed that many of the movements of brook lampreys are not very 'purposelike', and Hussakof remarks the same defect in the sea-lamprey. 'Thus a lamprey will sometimes pick up a stone outside the nest, carry and drop it into the nest; or while carrying out a stone will drop it half-way up the side of the nest. It will tug at a large stone which it cannot possibly dislodge, or at a log, in an effort to drag it out of the nest, and will repeat this again and again, without profiting in the least by previous failures. On the whole, one has a feeling that the lamprey possesses a very low mentality, even as compared with fishes'. They seem to be guided greatly by touch, and they exhibit a curious preoccupation with their work, paying no heed, for instance, to onlookers or to the noise of automobiles clattering over a wooden bridge above the nest-building. But whether this apparent absorption in their work may be due to sensory dullness, we do not at present know. In any case, stupid or not, these old-world creatures do not choose the path of least resistance; alike in their migrations and in their nest-buildings they afford us abundant food for wonder.

CHAPTER VII

THE WONDER OF LIFE

(Characteristics of Living Creatures)

'Past and future are unknown to her. The present is her eternity. She is beneficent. . . .'

'She is complete, but never finished. As she works now, so can she always work. . . .'

'She is ever shaping new forms; what is, has never yet been; what has been, comes not again. Everything is new, and yet naught but the old.'

—*Goethe's Aphorisms*, translated by Huxley.

The Creature Itself—Organisms and Mechanisms—The Insignia of Life—Down-breaking and Up-building—The Power of Growing—Capacity for Behaviour—Power of Reproducing—Development—Variability—Simulacra Vitæ—Difficult Phenomena—The Powers of Life—Correlation—The Subtlety of Life—Adaptation—Regeneration—The Crowning Wonder of Evolution—Vitalism.

WE have considered organisms as actors in a drama, living in haunts, conquering space, trading with time, and passing from phase to phase in their individual life-histories. Let us now change our point of view and think of the living creature itself. What are the great facts in regard to it and its living that stand out when we get to a little distance, and are not embarrassed by the details of anatomy, physiology, embryology and the like?

The Creature Itself

Were it not for the difficulty of seeing things clearly, thoroughly, and imaginatively, all educated men, with

opportunities of enjoying the observation of life as it is lived in Nature, would be unanimous in admiration of every living creature. The normal outlook, admittedly difficult to attain to, is expressed in Walt Whitman's well-known creed :—

'I believe a leaf of grass is no less than the journey-work of the stars,
And the pismire is equally perfect, and the grain of sand, and the egg of the wren,
And the tree-toad is a *chef-d'œuvre* for the highest,
And the running blackberry would adorn the parlours of heaven,
And the narrowest hinge in my hand puts to scorn all machinery,
And the cow crunching with depressed head surpasses any statue,
And a mouse is miracle enough to stagger sextillions of infidels.'

Organisms and Mechanisms.—Both in teaching and in investigation it is very useful to compare living creatures to engines. Both are material systems for the transformation of matter and energy. But the analogy is most useful when it breaks down, for then the insignia of life stand out in relief. Professor Joly long ago pointed out one of the deep differences between an inanimate material system and a living organism :

'While the transfer of energy into any *inanimate* material system is attended by effects retardative to the transfer and conducive to dissipation, the transfer of energy into any *animate* material system is attended by effects conducive to the transfer and retardative of dissipation'.

Charging a Leyden jar or heating a bar of iron is attended by effects very different from those which attend the feeding of an animal.

But without dwelling on this technical difference, though it seems to us far-reaching, we may emphasize the fact that the efficiency of the living creature considered as an engine

is surprisingly greater than that of our best engines. A steam-engine, for the most part made of iron, is a material system for transforming the potential energy of coal into heat and work. A living organism, in great part built up of proteids, carbohydrates, and other carbon-compounds, is also a material system for transforming the potential energy of food into heat and work. But the living organism, considered as an engine, is much more effective than the locomotive. For while the best steam-engine turns only about twelve per cent. of its income of potential energy into work; the animal can give back as much as twenty-five per cent. Moreover, the actual waste of heat in the steam-engine is much greater than in the animal.

We need not elaborate the contrast between living creatures and engines. To any one bent on maintaining that organisms *are* engines, we would point out that they are self-stoking, self-repairing, self-regulating, self-adjusting, self-resting, self-increasing, and self-reproducing engines!

In his interesting book, *The Cell as the Unit of Life*, Dr. Allen Macfadyen wrote:—

'A great part of physiological inquiry has consisted in the examination and explanation, not of *life* but of the mechanism of life, and so far as this mechanism is concerned, adequate and satisfactory explanations have been found in the ordinary laws of physics. It is when we come to cellular activities that our real difficulties begin as regards the essentially vital problems'.

It is interesting to look up the works of Professor W. Roux, a hard-headed anatomist and embryologist, the pioneer in the modern study of 'developmental mechanics', to notice how constantly, in spite of that word 'mechanics,'

which he uses in a wide sense, he refers to ' self-preservation ', ' self-increase ', ' self-adjustment ', ' self-differentiation ', ' self-regulation ', and so on.

Another note may be useful at this stage, that an engine or a machine is not exactly a fair example of the inanimate world. It is a sort of non-protoplasmic extension of man's hand. It is a human invention. One of the famous automata had a clever dwarf shut up inside, and in a way there is a human idea inside every machine. This makes a difference.

The Insignia of Life.—What are the radical differences between a bird and the stone that kills it, between a tree and the snow-crystals that transfigure it? What does livingness really mean? As the innermost secret of life eludes us, this section of the chapter might end with the mark of interrogation. On the other hand, while we do not understand what the essence of life is, it may not be unprofitable to treat living creatures descriptively, asking ourselves how they differ from not-living things.

Many have tried to state in a few words the characteristics of living organisms, but no formulation has won general acceptance. The best we know is given by Roux, who recognizes five ' elementary functions ' :—

I. Self-disassimilation.

II. Self-preservation, including assimilation, growth, movement, feeding, etc.

III. Self-multiplication.

IV. Self-development.

V. Self-regulation in the exercise of all functions, including self-differentiation, self-adjustment, self-adaptation, and in many organisms distinctly recognizable psychical functions.

Altogether, according to Roux, there are thirteen general characters of living creatures, and we do not know of any that he has omitted. Yet we venture to arrange the characteristics somewhat differently.

Down-breaking and Up-building.—Every normal organism is like a whirlpool in the river, always changing and yet more or less remaining the same. It is like the sunlit top of a fountain rising in the air; its component elements are restlessly changing on their way up or on their way down. Like a clock it is always running down and always needing to be wound up; but unlike a clock it can wind itself up. Not indefinitely, indeed, but some of the Californian Big Trees (*Sequoia gigantea*) did it, as we have seen, for two thousand years—genuine Methuselahs! The constructive, synthetic, up-building or winding-up processes are summed up in the term *Anabolism*; the destructive, analytic, down-breaking, running-down processes are summed up in the term *Katabolism*, and both are included in a term that covers both, *Metabolism*, for which we have, unfortunately, no English equivalent—no word like the fine German word 'Stoffwechsel', change of stuff. Chemical change is universal, of course, but the peculiarity in the case of organisms is the balancing of accounts, the correlation of up-building with down-breaking, of the winding-up with the running-down. That is the criterion of vital processes, biologically considered, that they go on of themselves, that they form part of a concatenated series of chemical processes somehow bound into unity, a series in which the pluses balance the minuses, and the thing goes on. It is idle to try to express it in terms of what goes on in the sterilized chemical laboratory, for, taken as a whole, it is something more. Isolate any

particular reaction, and it is the same in the eagle as in the test-tube; but the riddle of life is that of the burning bush—*nec tamen consumebatur.*

The Power of Growing.—Given a material system that could balance accounts, that did not simply run down brilliantly and fizzle out, like the flaring pill of potassium thrown on the basin of water, the logically second criterion is growth or self-increase. A surplus of income over expenditure, that is the primal condition of organic growth (for crystal growth and osmotic growth is not relevant at all); the essential criterion is that out of material quite different from itself the living creature is able to meet not only current expenditure, but to lay by something—for *growth.* That income should exceed expenditure is the obvious condition of organic growth.

The Capacity for Behaviour.—The growth of an organism implies an active assimilation, not a passive accretion, but it makes more venturesome activity possible. Having some reserves in hand is one of the conditions of agency. In some of the simplest organisms it has been observed that movement stops when certain substances included in the living matter are used up, and does not begin again until they are replaced. They are among the conditions of behaviour, just as food and water are among the conditions of the continued progress of a band of explorers. But the life is more than meat.

When we study the activities of the very simplest organisms we do not find that they are simple. The movements of advance and retreat and re-advance exhibited by some of the mysterious slime-fungi (Myxomycetes) are beyond any re-description in terms of present-day chemistry and physics. They exhibit the rudiments of behaviour.

The flowing movements of an amœba cannot be interpreted as a result of local changes in surface tension, or the like. Though surface tension phenomena are involved, the movement is self-determined. Professor Jennings has described the behaviour of an amœba which pursued a spherical cyst of Euglena for fifteen minutes. One amœba pursued another for a long time, finally capturing and ingesting it. But after being carried for a short distance, the prey partly escaped and was recaptured. It again escaped, this time completely, but was pursued, overtaken, recaptured, and again carried away. After five minutes it escaped again, this time completely and successfully, so that the hunter amœba did not have its meal after all. But this is more than surface tension.

It seems to be one of the insignia of life that the organism registers within itself the results of its experiences. As Professor W. K. Clifford said: 'It is the peculiarity of living things not merely that they change under the influence of surrounding circumstances, but that any change which takes place in them is not lost, but retained, and as it were built into the organism to serve as the foundation for future actions'. As Professor Henri Bergson puts it: 'Its past, in its entirety, is prolonged into its present, and abides there, actual and acting'.

To begin with, there must be a viable balance of up-building and down-breaking—the essential *modus vivendi*; then there must be addition to the specific structure, so that some rest is possible in one part while another is working hard; along with that will go the accumulation of some capital, so that the organism is not always living from hand to mouth; this makes more energetic action possible, and more thorough re-creation of the specific

structure. Thus we may begin to think of the conditions of agency, of experimenting, of trafficking with time, and of multiplying.

Power of Reproducing.—Growth is self-increase, and it leads on to reproduction which is self-multiplication. In a simple organism—a nucleated corpuscle of living matter—growth proceeds up to a certain point which we call the limit of growth. Beyond that it is dangerous for the corpuscle to grow, unless indeed it secures at the same time great increase of surface. We have already referred (p. 396) to what was pointed out by Herbert Spencer and others, that if the corpuscle be a sphere, as it often is, the volume (whose contents have to be kept alive) increases as the cube of the radius, whereas the surface (through which the keeping alive is effected) increases only as the square. Thus if it grow beyond a certain size, the corpuscle gets into difficulties. There is also an optimum ratio between the nucleus and the rest of the cell-substance.

Development.—We are trying to see the essential criteria of life in a logical order. The power of sustained metabolism—of balancing accounts—makes activity and growth possible; growth naturally leads on to multiplication; and the power of development that an isolated fragment, or sample, or, it may be, germ-cell possesses of re-expressing the whole is surely a continuation of the restitution and regrowth which goes on to make good the body's wear and tear, and of the regeneration which is exhibited when a lost part is replaced. Development is the making visible of the latent manifoldness of the liberated fragment, or sample, or cell. It is the expression of latent possibilities—it is, subjectively regarded, a kind of self-expres-

sion. Out of the apparently simple there arises the obviously complex, as the chicken is 'coined and minted out of the egg'. There are the two great processes :—differentiation (which is the structural side of division of labour), and integration (which means the unification and harmonization and controlling of all the parts). The developing creature becomes more visibly complex; it also becomes knit together as a unity. Development always implies these two processes.

Variability.—It is well known that some of the simplest organisms—which remain single cells—occur in different forms and with different qualities in different circumstances. Thus the same Bacterium may be virulent or relatively attenuated in its poisoning capacity, and 'polymorphic' Protozoa, e.g. some Trypanosomes, are described. It does not seem that these diversities are simply individually acquired peculiarities, due to some peculiarity in the particular environment. They may have arisen in some such way, but they often appear to have taken grip of the constitution; they are not individual, but racial peculiarities, and will persist for a while even when the environment is altered.

This variability of the living organism is characteristic and fundamental. It has to be accepted, at present, as a primary fact of life, but some suggestions may be considered which tend to leave it less apart. In the inanimate world there is a tendency in matter to complexify, for atoms to build up molecules, and molecules larger molecules, and so on. There is also a certain variability in the crystallization of one and the same chemical substance, which may appear in several different forms. Every one has looked at the beautiful diversity among snow-flakes. Now it may be

that the tendency to complexify that is seen in things inanimate is carried on into organisms, and finds expression in variation.

There are many peculiarities in the bodies of higher animals which are certainly not the direct results of some peculiarity in the environment, but are, we believe, the expression of variations in the germinal substance. Yet it has to be remembered in regard to these variations that the environmental peculiarities may have served to prompt the germ-cells to some internal re-arrangement of their organization.

Weismann has laid emphasis on the fact that the germinal substance in the germ-cells is subjected to the changes and fluctuations in the nutritive stream, and it is possible that these may serve to prompt germinal variations. He has also suggested that there may be within the germ-cell a literal struggle among the hereditary items or factors, just as there is a struggle among the different parts of the body.

Another consideration is this, that in the ripening of the egg-cell there appears to be an opportunity for the dropping out of hereditary items, and as a matter of fact we know that items are very often dropped out. In albinos a pigment-producing or pigment-completing factor is dropped out. Moreover, in fertilization, as we have seen, there are opportunities for new permutations and combinations, when the paternal and maternal contributions enter into intimate and orderly union. Two sex-cells become one—a unified individual, not merely an inheritance-packed cell. In the compromise effected between similar items, in the unified organization arrived at, there is probably many an opportunity for something new.

Simulacra Vitae.—Bütschli, following Quincke, showed how mimic cells might be produced by putting drops of fine emulsions in suitable media. Some old olive oil beaten up with a little powdered potassium carbonate forms a very fine emulsion—an acid in the oil attacking the salt and liberating microscopic vacuoles of carbon dioxide. The resulting emulsion is a microscopic foam, and micro-photographs of drops of it look like micro-photographs of some kinds of cells. For a time this resemblance gave corroboration to the view that the minute structure of cell-substance or cytoplasm was of the nature of a very fine foam or emulsion, though of course made of very much more complex materials than olive oil. It cannot be said, however, that recent histological research has given support to this interpretation.

It is doubtful whether these simulacra vitæ throw much light on the structure and activity of living cells, though it is quite probable that they may have a bearing on the formation of non-living bodies made by organisms, such as shells and pearls, spicules and calcareous corpuscles. If a weak solution of gelatine is spread on a slide and tiny drops of ferrocyanide of potassium are put on at intervals of five millimetres or so, the result is the production of rather striking simulacra of nucleated cells. But do these simulacra in relatively simple material throw much light on the structure of vital units? They are as remote as concentrically laminated agates are from tree-stems, as remote as the beautiful dendritic growths of manganese dioxide are from zoophytes.

Professor Stêphane Leduc has given much time to the study of wonderful inorganic growths which he is able to induce, and they certainly show what complex and beauti-

ful structures may arise in relatively simple media. Thus if fragments of calcium chloride be dropped into a litre of distilled water containing sixty grains of silicate of potassium, sixty grains of saturated solution of carbonate of soda, and thirty grains of saturated dibasic phosphate of soda, then beautiful phantasms arise—'osmotic growths'—like mushrooms and moulds and corals and shells. They show us the possibilities of inorganic growth, and perhaps they may be of service in bringing into stronger relief what is distinctive in organic growth. They may be of use for comparison with osmotic phenomena in organisms, but we are unable to see that they throw much light on the essential nature of growth in organisms. It appears to us to be giving an entirely false simplicity to the facts to suggest that Biology is a subdivision of the physico-chemistry of fluids. This is a survival of the uncritical materialistic superstition, and to credit the artificial osmotic growths with nutrition, assimilation, irritability, and a power of development is a bad instance of an assertion that outstrips its evidence.

Difficult Phenomena.—However much more it may be, living certainly is the correlation of a series of physical and chemical processes that go on within the organism. But it is impossible to ignore a thicket of difficulties. Even after the organization has been fatally shattered, parts of the body may continue active. A wasp, indeed, may continue sucking syrup though some tough friend of the public comfort has cut right through its waist. On the other hand, it is not easy to find evidence of activity in the hibernating snail, or in the resting pupæ of some insects, and yet life has not sped. There is nothing in either case by which we could very readily prove to the sceptical that death had not

occurred, though microscopic examination would show that some of the cells were alive. But how much more difficult the question becomes when we pass to dried up paste-eels, small thread-worms or Nematodes of the family Anguillulidæ, which can remain dry and brittle for as long as fourteen years, and yet become lively again when restored to water! What is life in these inert threads, which exhibit no sign of living? What has happened in the fifteenth year, when although no visible change has occurred, the threads are no longer susceptible to the reviving influence of water? They are dead; but what has happened?

Latent Life.—The familiar sight of bags of dry seeds in the seedsman's shop raises many questions. In what state is the life of these seeds—for it is to be hoped that most of them are still alive? Can they remain alive without actually living? Vital processes involve chemical change (metabolism): has metabolism come to a standstill or is it going on very slowly? It is not so easy to test this as might be imagined, for the fire of life may be kept burning so very, very low that no change is detectable in the surrounding medium. Some plants can respire without taking in oxygen from outside, and some others, e.g. succulents, can respire without giving out any carbon dioxide. Of course if the protoplasm is actually living it is transforming energy, and if it has no income it must be living on its own resources, therefore the life of seeds must be limited. We know securely from Becquerel's careful testing that seeds may germinate after resting for eighty-seven years in a herbarium—a *hortus siccus* indeed.

Becquerel has made important experiments on the latent life of dry seeds. He showed, for instance, that the

dry seed-coats of peas and beans, and of many others which can germinate after prolonged desiccation, are *air-proof*. When detached pieces were fitted on to the top of a tube of mercury, above a Torricellian vacuum, no air was drawn through—even in months. Thus a dry seed is peculiarly isolated. When the coats are wet, the absorption of water changes the situation, and gaseous exchange begins.

Becquerel's later experiments are very striking. He took seeds of wheat, mustard, and lucerne, and perforated their coats; dried them in a vacuum at 40° C. for six months; sealed them up in an almost exhausted tube for a year; submitted them to the temperature of liquid air (−190°) for three weeks, and of liquid hydrogen (−250°) for three days; and then put them on moist cotton wool—and they germinated as usual! In a review, Prof. Cavers gives a terse statement of Becquerel's conclusion. 'Becquerel finds it impossible to conceive of "life" under the conditions to which these seeds were subjected, and holds that life can be interrupted completely—not merely slowed down—with no prejudice to its resumption'.

Various fungoid organisms have been known to survive twenty-two years' desiccation; various bacteria have remained alive without air but with moisture for ten to twenty years; sediments containing various Protozoa have shown re-vivification after five to six years. J. Noc relates that some tubes with a little water and various Protozoa were hermetically sealed in 1908, and were recently examined. There was no trace of the Infusorians which were there to start with, but there were encysted Amoebae, some of which revived after ten days or so. Some Protozoa dried on Tonkin commercial paper were

revived after five years. One of these was a small Flagellate, *Oikomonas termo*.

Local Life.—The phenomena of local life demand careful consideration. On the one hand, we have many cases of fragments which grow into wholes. On the other hand, we have curious examples of parts which can live on for a long time after the whole has been destroyed, though they show little or no power of regeneration. Let us illustrate the first set of cases first. Every one knows that a piece of a branch or a piece of a potato will remain alive for a considerable time after being cut off, and will in appropriate conditions grow into a complete plant. Posts of wood, believed to be dead, sometimes burst into leaf after they have been driven into the ground. A small fragment of many a plant, from Liverwort to Begonia, will grow into a complete plant. And similarly, a fragment of sponge, of hydroid, of sea-anemone, of certain worms, and so forth, can regrow the whole. There is need of precise experiment to determine the limits and conditions of these regenerations of wholes from parts. In the case of Hydra, it has been found that the regenerating fragment must not be too small—a quantitative limit, and that it must contain samples of the different kinds of cells in the body—a qualitative limit. A tentacle will not regrow a polyp, though a polyp soon regrows a tentacle. Very extraordinary are the recent experiments of Professor H. V. Wilson which show that some sponges may be minced up and strained through a cloth strainer—and yet the debris poured out in an appropriate place will develop into a proper sponge. It is a verification of one of the old myths—of Zagreon, who was cut into pieces and yet survived.

As to the second set of cases, where parts live on though

without regenerative power or only a little of it, we may recall the familiar case of the turtle's heart, which, in appropriate conditions, will continue beating for several days after the bulk of the animal has been made into soup, and has passed into a new incarnation. There it goes on beating in its warm and humid glass case—a fine illustration of local life.

Of recent years very remarkable experiments have been made in keeping pieces of tissue alive in suitable media outside the body. What happens in most cases is that they live on for a time, grow a little, and die. Perhaps we should know a good deal if we understood why they die. It has been suggested that the death may be contingent rather than necessary, that it may be due, for instance, to the accumulation of waste products. With this idea in mind, Alexis Carrel has devised a system of artificial rejuvenescence, washing the piece of tissue from time to time in 'Ringer's solution', and placing it in a medium of plasma and distilled water. A piece of connective tissue revived nine times after this bathing treatment—staving off senescence and death for more than a month after its removal from the body.

Every one knows that egg-cells can remain for a long time alive but without developing. Much more remarkable is the fact that spermatozoa can be kept alive in a salt solution for a week. Very much more remarkable is the fact that isolated red blood corpuscles, of the newt for instance, can be kept alive for a fortnight. Jolly took a small quantity of blood directly from the newt's heart, put it in a tube placed in ice, and found the white blood corpuscles alive after 4½ months. Verily the tenacity of life is great.

Powers of Life.—Life is a powerful kind of activity. We see this in many ways—in the power of self-increase that is so characteristic of living matter, one Infusorian becoming a million in a week; in the associated power of transforming matter, the green plant changing air, water, and salts into bread, the animal changing the plant into flesh; in the economical transformations of energy, for as we have already mentioned, an organism considered as an engine gives more return for the potential energy supplied to it (the food or fuel) than any engine of man's device; in the capacity for storing potential energy without much leakage, as we see so convincingly in the trees of the forest; in the manifoldness of the energy-transformations that are accomplished, for we find one and the same creature doing work, giving off heat, giving off light, and exhibiting electrical changes; in the exquisite responsiveness, for a sundew tentacle will detect the presence of a minute drop of ammonium carbonate added to a large jar of water, and the earthworm, though without ears, is aware of the light tread of a thrush's foot. As it is impossible to discuss all the powers of life, our method must be, as throughout, only illustrative. We shall discuss two powers or capacities as different as possible—the power of giving forth light, and the power of taking a rest in sleep.

Luminescence.—In illustration of the powers of life, let us take the phenomenon of luminescence, or, as it has been erroneously called, phosphorescence. From the chemico-physical point of view, the organism is a material system which effects the transformation of matter and energy. It is the seat of continuous chemical changes—oxidations and reductions, hydrations and fermentations—which we sum up in the term metabolism. There is no

doubt that the production of light is one of the results of this metabolism. Just as heat is produced by the vital activity of the muscles (their characteristic 'thermogenic' function) and by all the combustions that go on in the body, so light is produced in connexion with other chemical processes involved in living. Many facts point to the con-

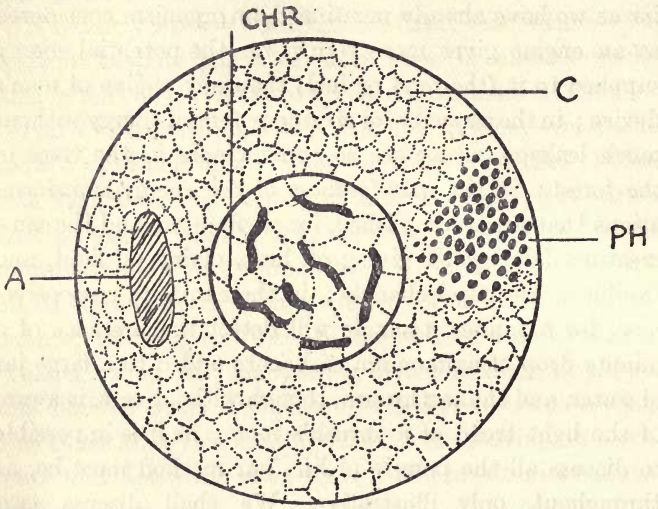

FIG. 78.—Phosphorescent cell. (*After* Watase.) C, Cytoplasm of the cell; CHR, Chromosomes of the nucleus—living constituents. A, Food; PH, Photogenic Granules—not living constituents. Oxygen acts on the photogenic granules, and Light emanates from the cell as the result of oxidation.

clusion that the luminescence need not be in itself of any biological importance, any more than the heat produced in the active brain is normally of any importance, any more than the beautiful colour of some organic waste products is in itself of any importance. But just as the production of heat or of pigment may be turned to good

account and made vitally important, so it may be with the production of light.

The facts in regard to luminescence in organisms raise many unanswered questions and demand further investigation, but there is no particular difficulty about the bare fact that light is produced in laboratories which give off heat, as we all experience, and generate electricity, as we may experience on close acquaintance with the Electric Eel or the Torpedo.

A noteworthy fact in regard to luminescence is its wide distribution in the sea. When the oars drip sparks on a summer night we see the luminescence of Noctiluca; and there are many pelagic animals—some Radiolarians, some Medusæ, most Ctenophores, some 'worms', many crustaceans, a few molluscs, Tunicates like the splendid Pyrosoma, and various surface fishes—which are luminescent. In the shore area there are luminescent Echinoderms, especially Brittle-stars; the boring Pholads—with their miners' lamps; and various members of the great alliance of Stinging Animals or Cœlenterates. In the great abysses, as we have noticed, luminescence is common, e.g. among Alcyonarians, Medusæ, Echinoderms, Crustaceans, Cuttle-fishes, and true fishes. On land we know it best in glow-worms, fire-flies, and other insects, but it also occurs in some Myriopods (e.g. *Geophilus electricus*), and in some earthworms (e.g. *Photodrilus*). It is usually said to be quite absent in freshwater animals, but we have some suspicions as to the accuracy of this generalization, bearing in mind Nelson Annandale's freshwater Lampyrid and allegations of luminescent Chironomid larvæ. That there are phosphorescent Bacteria is well known—every one can see them on fish hung up to dry—and it is probable that

reports of luminous birds are due to luminescent fungi on the plumage.

In a case like the luminescence of Bacteria, no one even looks for a utilitarian explanation. The luminescence is a by-play of vitality; it is one of the residual powers of the organism; and it is probably exhibited in many cases in which we do not and cannot see it. What we need to know is (1) the internal physiology of luminescence, and (2) what its use may be in certain cases where it bears the marks of specialization.

The luminescence is in some cases indissolubly connected with the cellular metabolism—as in Noctiluca, Brittle-stars, and some fishes. When they die their light goes out. In other cases the luminescent material is not luminescent until it is exuded from its producer into the water, as in many Copepods. The light does not require contact with life to keep it shining. The trail of the luminous Myriopod is luminous, and in some cases (Copepods, Lampyrids, and Pholads) the luminous secretion can be dried and yet retain its capacity of giving forth light when it is put into water after several days, weeks, or months.

In the American Lampyrid beetles, popularly called fire-flies, the light-producing organ, as described by McDermott and Crane, consists of two layers. The inner one, white and opaque, seems to serve as a reflector, and perhaps protects the insect from its own brightness. The outer one, yellowish and translucent, is the seat of the actual photogenic process. It is interesting to know that innumerable air-tubes or tracheæ penetrate the organ, for this bears out the conclusion otherwise arrived at, that the luminescence is due to an oxidation.

In the American fire-fly both sexes are luminescent, the

flightless female less so than her active partner. The luminescent organs of the male consist of a pair of plates, lying beneath the skin on the ventral surface of the fourth and fifth abdominal segments. Each plate has two layers, and the lower is built up of polygonal cells filled with coarse granules. In this lower layer there is probably a rapid oxidation of some unstable substance, perhaps of a fatty nature. It is possible that the decomposition may be accelerated by some ferment. Mrs. A. B. Howard has called attention to the fact that the light is unaccompanied by perceptible heat. It is therefore produced at the least possible expenditure of energy, as Professor Langley long ago pointed out.

In fire-flies of the genus Luciola the light given off has a beautiful green fluorescence, and is able, like X-rays, to affect a photographic plate through opaque media, such as layers of wood or leather. The light cannot be taken as phosphorescent, but includes rays which are, at least, 'similar to X-rays and ultra-violet light in so far as they render certain opaque media transparent, and are intercepted by glass'.

In an interesting study on the luminous organs of cuttlefishes, Dr. W. E. Hoyle calls attention to their occurrence in so many and such scattered families, that repeated and independent origination seems probable. They are almost always on the ventral surface of the Cephalopod, but they occur there in nine different situations. Sometimes they are concealed beneath the mantle or beneath the skin, but they may be effective even then, since the living tissues of cuttlefishes are very transparent. It is plausible to suppose that they serve as recognition marks, and that they act as searchlights, playing over the floor of the sea.

Some of them are simple, but others have a complicated optical apparatus with some or all of the following structures —pigment layer, reflector, lens, and diaphragm. While we may say that the production of light is parallel to the production of heat in a muscle or of electric discharges in *Torpedo*, there must be some definite utility when the organs have a complicated apparatus. Very noteworthy is the remarkable economy of the illuminant; a quite infinitesimal proportion of the energy is wasted on the production of heat.

In two surface fishes of the Malay Archipelago, *Anomalops katoptron* and *Photoblepharon palpebralis*, studied by O. Steche (1909), there are very large luminous organs about the head, which seem to give out a constant light without requiring any particular stimulus. The luminescence has its seat in material secreted by glandular cells, and occurs outside the cells in the cavity of the gland which they form. In the fishes we have mentioned, the luminescent organ can be, so to speak, extinguished by a downward movement, which possibly takes place when an enemy appears on the scene.

Messrs. Holt and Byrne describe a remarkable deep-water fish, Lamprotoxus, from the south-west coast of Ireland. It bore a filamentous barbule many times longer than the body. The colour of the scaleless skin was velvety-black and the barbule was grey. A purplish-grey cord-like band of luminous tissue, partially embedded in the skin, formed a closed loop on the anterior part of the body. There was also a large photophore behind and slightly below the eye, occluded by skin save for a narrow slit; and there were numerous very small photophores.

There is little direct evidence as to the use of luminescence,

and, as we have said, there are probably many cases where it is of no use. But this cannot be the case when it is associated with highly specialized organs. And when we see a female glow-worm with luminescent organs on the under side of the body turning herself back downwards with the result, at any rate, that her light is visible, we find it difficult to believe that the light is not attractive to

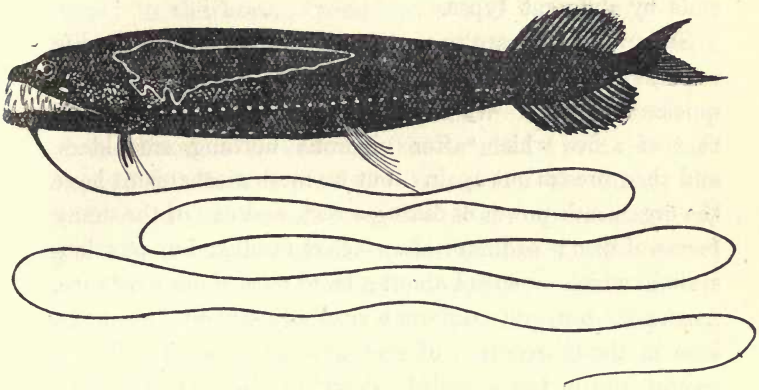

FIG. 79.—A remarkable fish, *Lamprotoxus flagellibarba*, from deep water off S.W. of Ireland. The small spots and the 'looped band' seem to be luminous organs. The barbel is many times longer than the body, which is about seven inches in length. (*After* Holt and Byrne.)

the male. Many animals move towards a light, and it is a very probable view that the luminescence of many marine animals helps to bring food to them. Professor Max Weber mentions the very interesting fact that the fishermen of Banda cut out the luminous organ of Anomalops and similar fishes, and use it as a bait, for it keeps on shining for hours. A sudden illumination of a luminous organ, or a sudden discharge of a luminous secretion may have a protective

value. In the darkness of the great abysses some animals may possibly use their luminous organs as lanterns. Where the luminous organs are arranged on a definite pattern—which is sometimes different in the two sexes—it is quite likely that they serve as recognition marks. But for our present purpose it is enough to indicate that this peculiar transformation of energy—not in itself necessarily useful—may be seized upon, utilized, and specialized towards diverse ends by different types.

Sleep.—It appears to us to be characteristic of the life or activity of organisms that it can be slowed down and quickened again. We may hunt out analogies, such as that of a fire which, after vigorous burning, smoulders, and then breaks out again; but no mere mechanisms have the organism's power of taking a rest, and one of the many forms of rest is ordinary sleep—that familiar but puzzling state in which we spend about a third part of our existence. Analogous but quite different vital adjustments are to be seen in the hibernation of such animals as snail and dormouse, and in the so-called 'sleep' of plants which often makes itself plain in the altered position of the leaves and the closing of the flowers.

Normally, there can be no doubt, the sleeping habit was established in relation to sunset, but every one knows that we can adjust our capacity for going to sleep so as to suit our particular circumstances. The important point is, that once the habit is established, say of going to sleep at 11 p.m., it asserts itself with some insistence unless the attention is strongly diverted. In the course of a short time, varying with the individual, the rhythm can be changed and the man sleeps as soundly (other things equal) by day as he formerly did by night.

Animals accustomed to sleep will die in a few days if they are deprived of it; in some cases, much sooner, as has been shown experimentally, than if they are deprived of food. What, then, is it that goes on during sleep that makes it necessary? What is the physiological condition during sleep?

In a recent lecture, Legendre summed up the state of affairs:—Digestion goes on, and this may lessen the blood-supply to the brain; perspiration and excretion go on; the respiratory movements are altered, being usually slower, deeper, and more regular; relatively less carbonic acid is given off; the body temperature falls; the action of the heart is slowed and the arterial blood pressure diminishes; there is a relative anæmia of the brain; the working of the sense-organs is altered; the muscles are generally relaxed and the reflexes tend to disappear; and there are other differences of a subtler sort. But it cannot be said that there is in this narration anything that in particular gives us the clue to the significance of sleep.

There is a superabundance of theories in regard to the cause of sleep, but, until recently, it was the delight of physiologists to show that none of them was adequate. It has been suggested that a relative anæmia of the brain left the nerve-cells without enough of food or encumbered with imperfectly removed waste. It has been suggested that changes in the condition of the blood produced sleep. It has been suggested that wearied nerve-cells contracted and lost that touch with one another that they have during waking hours. It has been suggested that the creature becomes irresponsive and indifferent to the outside stimuli that keep it agog in its waking hours. But, as Claparède

points out, these suggestions cannot be solutions; they simply shunt the problem. For why this periodic change in the flow of blood to the brain, why the retraction of the nerve cells, why the unresponsiveness to outside stimulation?

In a luminous lecture on sleep, Professor Fraser Harris distinguishes four types—chemical, vascular, sensory, and psychic. (1) Sleep may be due to fatigue-toxins, the poisonous waste-products of exertion, just as it may be induced by drugs. The nerve-cells in the brain no longer exhibit their normal interlinking (or synapsis); there is resistance to incoming sensory messages. Men fall asleep in the saddle or on forced marches, and Holbein fell asleep when swimming the Channel. (2) Sleep may be due to diminution of the velocity of the cerebral blood flow, just as may occur abnormally in some kinds of fainting. It has been shown that the sleeping brain is paler, there is less blood and a lower blood pressure. Mosso devised an experiment of balancing a wide-awake man accurately on a table, and showed that when he fell asleep the foot end of the table sunk—the dip indicating the depth of sleep. When the heart is excited we cannot sleep. (3) Sleep may be due to sensory changes, to an increase of the 'resistance' at the interlinking (or synapsis) of the cells in the sensory centres of the fore-brain, or a diminution of conductivity at these interlinkings. When sensations force their way in we cannot sleep. (4) Sleep may be due to the absence of emotions and ideas; thus stupid people fall asleep easily. As Bergson has said, we do not go to sleep if we are more interested in anything else than going to sleep. When we are worried we cannot sleep.

Another approach to the problem of sleep is in the light

of general biological facts. All activity implies a using up of material, a using up of oxygen, and the formation of waste-products. The nerve cells are in no way exempted, and it has been demonstrated visually that the brain-cells of a bee that has been working hard all day are in a different condition from those in a brain that has been resting. In a case of prolonged insomnia there was said to be a disappearance of a readily stainable (chromatophilous) substance located in what are called 'Nissl's granules' in most nerve-cells. Moreover, the nerve-cells require to keep up a store of intra-molecular oxygen. And besides carbonic-acid gas, which is always being removed by the blood, there are subtler wastes, 'fatigue toxins', about which we do not know very much. The general biological view is therefore this, that persistent activity involves using up of material and oxygen and an accumulation of waste-products, such that the 'machinery' has to go more slowly, so that re-stoking and cleaning may be thoroughly effected. It is conceivable, indeed, that it might have been arranged that repair always kept pace with waste, and that the organism never got into any physiological arrears at all. It is probable that very simple organisms, such as the 'immortal' Amœba are in this happy state. But with increasing complexity this ceased to be possible, and sleep was invented. 'Blessed be the man', said Sancho Panza, 'who invented sleep', but we do not know at what precise level of organization the invention was discovered. Probably not until the cerebral cortex was well differentiated.

The general biological theory is consistent with many familiar facts:—The greatly fatigued organism falls asleep; it awakens from sleep refreshed. And it is remarkably confirmed by Legendre's delicate experiment of injecting

into a normal animal the serum, or, better, the cerebro-spinal fluid of an animal exhausted by loss of sleep. In about half an hour there is induced an imperative need for sleep.

'The animal so injected is benumbed little by little, its eyelids blink, its limbs relax, its eyes close, it loses all attention, and it responds but feebly to strong stimulation. Its brain presents the characteristic lesions of insomnia. The injections, under the same conditions, of liquids from a normal animal have no effect at all'.

It seems evident, then, that in some form or other, the injection from the exhausted animals acts like a sleeping draught.

It seems to us very probable that there are many cases where this general biological theory of sleep is quite sufficient. The successful long-lived animals are those that can take rests. There has been an age-long selection of the methodical, who work when they work, and rest when they rest. An established rhythm of alternate working and resting pays best, and it has become conveniently hitched on to the great external periodicity of day and night. The works have to be slowed down to permit of re-stoking and thorough cleaning, and these functions are effected most readily when their recurrence is rhythmic.

It is very interesting, however, to find Legendre, physiologist as he is, declaring that although physiology has important and fundamental contributions to offer towards a theory of sleep, 'physiology alone cannot dream of solving the problem'. We understand that his view has particular reference to Man and the higher vertebrates, where it seems that psychological factors must also be taken into account.

It appears to us probable, as we have hinted, that there are levels in the animal kingdom at which the purely physiological theory of sleep is adequate to cover all the facts. All sleep is not the same sleep, any more than all flesh is the same flesh.

Claparède objects to the purely physiological view on various grounds. One can sleep without being fatigued, and one may be too tired to sleep. If sleep were enforced by the accumulation of fatigue-poisons, how is it that many a man is so lively just a few minutes before he goes to bed? Could an auto-intoxication of the severity suggested be endured night after night for threescore years and ten? One of the Siamese twins could sleep while the other suffered from insomnia, yet their blood-vessels communicated! Perhaps there are answers to these objections, but we shall not go into that. Our point is simply to show that there are great difficulties in the way of the purely physiological theory. Claparède maintains that an adequate theory must be psychological as well.

Experiments made by Legendre and Piéron confirm the theory that specific waste-products or fatigue-toxins are formed during periods of prolonged wakefulness, that these permeate the organism, and particularly affect the frontal lobes of the brain. They prevented dogs from sleeping, while tiring them as little as possible, and found that about ten days was the limit of resistance.

'The temperature of the body remains normal, the respiration undergoes no variation, and the amount of carbon dioxide in the blood does not increase, which enables us to exclude the theories of the impoverishment of the blood in oxygen and its enrichment in carbon dioxide as the actual causes of sleep. Neither the blood nor the brain lose their

proportion of water, and this fact combats the theories that explain sleep by dehydration '.

When the animal can no longer keep its eyes open, and has become almost quite unresponsive, the frontal lobe shows cellular disturbances. If it is no longer kept awake, it plunges into deep sleep, from which it awakens completely refreshed. It is quite normal again, and the alterations in the brain have disappeared. It may be that these experiments are on the way to the discovery of an alleviation of one of the most terrible of human ills—*insomnia*.

Claparède's view is that sleep is more than a passive obedience to internal physiological necessities, it is an active defensive instinct. Just as the bird migrates in autumn before there is external coercion, so we go to sleep before there is an overpowering need. The physiological conditions, such as the fatigue-producing substances, pull the trigger of an old-established sleep-instinct. They serve to make us take for the time being a great interest in sleep. If a greater interest should be aroused, sleepiness disappears like magic ; the child who could hardly keep its eyes open, does not want to go to bed at all when there is sudden news of a great fire to be seen. When our interest for the moment is greater in sleep than in anything else, and that implies inducing external and internal conditions to which we have become habituated, then we are asleep before we know it.

It comes to this, that long ago, those animals got on best which established a rhythm of work and rest, corresponding on the whole to the periodicity of day and night, and later on that some of their successors got on best which developed

a sleep-instinct or hereditary predisposition to sleep, obedient rather to trigger-pulling physiological conditions than to coercive auto-intoxication or the like.

We cannot conclude this section on sleep without suggesting the desirability of trying to bring numerous distantly or nearly related phenomena into line. A great reward awaits the successful investigator. Perhaps it is impossible to put the numerous analogous phenomena into any one series, but it would be progress to know why this could not be. If we start with normal diurnal sleep, we have many associated phenomena, such as (*a*) very prolonged slumbers, (*b*) trance, (*c*) coma, (*d*) hibernation, (*e*) prolonged latent life. If we go back again to normal diurnal sleep, we have in another direction, or perhaps in other directions, such phenomena as fainting, catalepsy, the so-called sleep of insects, 'feigning death', paralysis. And then there are the various forms of artificial anæsthesia such as chloroforming (which has, of course, been very thoroughly studied), to 'the shortest way out of Slumtown', (which has been very thoroughly practised).

The Subtlety of Life

One of the most striking biological discoveries of the twentieth century is that of anaphylaxis—a difficult term for a very remarkable phenomenon which illustrates exceedingly well what we venture to call the subtlety of life. To understand what the phenomenon is, some introductory exposition is necessary.

It is well known that certain common infectious diseases, such as scarlet fever, produce a poison within the body, and that if the patient recovers he is for the future (in most

cases) invulnerable or 'immune' so far as that particular poison is concerned. In conquering the poison of the disease the body produces anti-toxins, which remain as a chemical body-guard, preventing the same disease from getting in again. In a similar way the anti-toxin produced as a reaction to the mild poison introduced in vaccination is a preventive or an immunization against subsequent poisoning from small-pox. This is the first point to be apprehended.

It is also very well known that there are many poisons, such as the nicotine of tobacco, which render the individual increasingly tolerant of them if their use is persisted in. Thus, the confirmed 'opium-eater' can imbibe or inject a dose which would immediately kill a normal individual, and which would have been fatal to himself if he had not accustomed himself to gradually increased quantities. De Quincey, in his *Confessions*, tells us that he gave to a wandering Malay who came to his door, a piece of opium large enough to kill six dragoons and their horses if they were not used to it! The Malay received it with delight, broke it into three pieces, and immediately swallowed them all. De Quincey's own allowance at one period of his life was said to be eight thousand drops of laudanum a day. In any case, it is certain that the body becomes increasingly tolerant of certain poisons.

Anaphylaxis.—The new fact which has been discovered by the eminent French physiologist, Professor Charles Richet, is that certain poisons when introduced into the system *enormously increase the susceptibility of the organism to the toxic action of that particular substance.* This fact was apparently not unknown to some of the earlier physiologists, but it was not clearly recognized as other

than an obscure anomaly (always a clue to be followed up), till Richet tackled it in 1902, and coined for it the name Anaphylaxis—a companion word to prophylaxis, which means protection against a disease. (See Richet's *L'Anaphylaxie*, Paris, 1912.)

Let us follow Professor Richet's work. One of his early experiments was with the poison in the stinging cells of the sea-anemone's tentacles—a poison which we can feel if we have the courage to put the tip of our tongue to the sea-anemone's mouth. Our finger will not suffice, for the poison-bathed lassoes of the stinging cells are not sufficiently strong to penetrate the skin of our hands. Richet made an extract by soaking the tentacles of Actinia in glycerine, and he injected the poison thus obtained into the veins of a dog. He found that a rather large dose was required to cause death, but what came to him as a surprise was the discovery that a dog which had fully recovered from treatment and was subjected to a fresh injection a month afterwards, succumbed to a dose of about one-twentieth the original strength. It might be suggested that the poison was cumulative, and that the second dose was the last straw that broke the camel's back, but the improbability of this was evidenced by the time that had elapsed since the previous injection and by the smallness of the second dose. The only possible conclusion from this and other experiments was, that the first dose brings about a peculiar physiological condition which makes the organism hyper-sensitive to subsequent doses.

A further step was taken in 1903, when M. Arthus showed that the anaphylactic condition could be induced by a substance, such as blood-serum, which is not in itself toxic. A rabbit, which had been injected with a dose of

horse-serum without showing any signs of disturbance, a month later succumbed at once on receiving an injection of one-twentieth the quantity of the original amount.

Anaphylaxis is invariably specific. That is to say, an animal which has been rendered hyper-sensitive to one particular substance, is not affected in any peculiar way by a subsequent injection of another substance, not even by a different kind of blood-serum. This has a curious application in the practice of medical jurisprudence. It supplies a new and conclusive method of determining the source of a quantity of blood, for instance whether it is human or not. Suppose there be in readiness a set of guinea-pigs which have been treated, a month or so before, with large doses of the serum of different creatures—man, dog, horse, and so on; a solution of the blood to be identified is injected into each of them; one reacts and the others remain unaffected; the blood to be identified came from the kind of organism whose serum had been injected into the guinea-pig which reacted.

Another remarkable experiment was made with guinea-pigs—for here, as in other cases, this stupid rodent justifies its existence by proving a remarkably fine subject for experiment. Its sensitiveness to a given substance may be increased five thousand times, which makes very delicate testing possible. The experiment was that of injecting into a set of guinea-pigs an extract of the muscle of a human mummy, and after an interval other muscle extracts from various organisms. But the guinea-pigs proved the specific nature of anaphylaxis, they reacted only to extract of human muscle, ' thus proving, if proof were needed, that the chemical constitution of the human body has not notably varied in the last three or four thousand years '.

The medical aspects of anaphylaxis do not concern us here, but we may note that Professor Richet regards the phenomenon as throwing light on the diagnostic value of tuberculin, and probably also on the occasional terrible accidents which for a time almost discredited it as a therapeutic agent. This latter point is still under investigation. The 'serum disease', too, which sometimes follows the use of anti-toxin and inoculation for plague is probably to be explained in the same way. Cases are described which seem to show that a substance may be prophylactic against a particular disease, bringing about a condition of immunity, and, at the same time, anaphylactic against itself, inducing hyper-sensitiveness to even small doses. The simultaneous development of immunity and anaphylaxis may serve to illustrate what we mean by the subtlety of life. From a practical point of view it is comforting to learn that the physiologists have already devised an 'anti-anaphylactic method of procedure'.

No crystallizable substance is known to produce anaphylaxis, but almost any colloid substance (i.e. an albuminoid unable or hardly able to pass through organic membranes) may do so under certain conditions. Among these conditions are, that a certain time—an incubation period—must elapse between the doses, and that the substance —serum, egg, milk, muscle-extract, vegetable extract, sea-anemone extract, or whatever it may be—must be introduced into the circulation. 'Alimentary anaphylaxis', i.e. through eating the substance in question, seems to come about very rarely, and the reason for this is obvious, since it is not the substance itself, but the result of the digestion of the substance, that passes from the food-canal into the circulation. But the rare exceptions are of great

interest, since they are the people known to us all, to whom 'eggs are poison', who cannot digest milk in any form, or who cannot eat a particular kind of shellfish without more or less serious symptoms, such as nettlerash and fever. Instances are known of people becoming very seriously ill through having unconsciously partaken of some disguised form of the substance to which they have such a violent constitutional antipathy. A scientific light is thrown on the adage, 'what is one man's food is another man's poison'. In this connection, again, the phenomenon of anaphylaxis is absolutely specific, and Dr. Richet cites the case of a man who always showed violent symptoms after eating even a perfectly fresh shrimp, yet who could indulge freely in lobster without inconvenience. He strained at a gnat, but could swallow a camel with ease.

Another complexity is what is called 'passive anaphylaxis'. That is to say, if the blood of an animal which has been anaphylactized in regard to a particular substance be injected into another animal, that also becomes anaphylactic to the same substance. A little seems to go a long way in producing a remarkable change. Interesting also is the fact that anaphylaxis in a mother, acquired either before or after conception, may be acquired by her offspring, so that they are born anaphylactic. Diffusion of a substance from the mother's blood to the offspring's must have occurred during the ante-natal life. But the condition of congenital anaphylaxis is not of long duration. In guinea-pigs it was noted on the forty-fourth day, but had disappeared by the seventieth.

Professor Richet's theory of anaphylaxis, that is of the precise way in which the condition is brought about, is too technical for our present purpose. Suffice it to say

that he regards the first introduction of the albuminoid substance as modifying the blood by producing in it, during the so-called incubation period, a chemical substance, which is not in itself toxic, but which is capable of becoming immediately and violently toxic in the presence of the original albuminoid.

Chemical Individuality.—One of the general ideas that rises in the mind after a consideration of some of the facts of anaphylaxis, is that of the chemical individuality of an organism. It is characteristic—fundamentally characteristic—of an organism that it carries its past into its present, that 'time bites into it' as Bergson puts it, and there is often very considerable variety in individual experience. Many different kinds of substances enter into the organism, and some of them may bring about modification, either in the direction of anaphylactization or immunization, and thus each individual of a species may differ from every other in chemical composition. We know indeed experimentally that there *are* these individual differences, some of them probably germinal or innate, some of them modificational or extrinsic, in origin. An individual is an individual not only to his finger-prints, but to his chemical molecules. And it seems to us that the anaphylaxis experiments clearly show that the vague 'idiosyncrasy' of the past must give place to a more definite conception of a chemical individuality which not only expresses the new unity which is established in every fertilized egg-cell, but embodies the results of the individual's physiological history, just as his psychological personality is ever registering his mental experiences.

But while there are minor idiosyncrasies (distinguishing between the individual members of a species, distinguish-

ing sometimes between the two sexes), there is also a typical specific chemical constitution which cannot be widely departed from if the species is to persist. The muscle extract of a modern man pulled the anaphylactic trigger in the guinea-pig which had been treated a month before with extract of mummified muscle. We know in other connections that there is a demonstrable specific difference between the blood of a horse and the blood of an ass. There is a specific chemical constitution which is on the whole the best for the species in question, being stamped with survival-merit after thousands of disadvantageous aberrations have been sifted away through thousands of years. Thus we come back from anaphylaxis to what was said of old: 'All flesh is not the same flesh: but there is one kind of flesh of men, another flesh of beasts, another of fishes, and another of birds'. We are here close to the idea of a chemical definition of a species, which will not be other than complementary to a psychological one. And it is here that Professor Richet makes a notable contribution, pointing out the *specific* or *racial value* of this curious property of anaphylaxis.

'I am more and more convinced', he writes, 'that every detail of the organism has a protective rôle, and is useful and even necessary to life, and that, therefore, a great general biological function like anaphylaxis must play an essential part in the defence of organisms. So that anaphylaxis appears to us an efficacious and energetic method of maintaining the chemical stability of our bodies by provoking an immediate and violent reactional response to the introduction of any substance which might change it. This is not the defence of the individual; it is the defence of the species at the cost of the individual'.

Individuality of the Blood.—What is called the serum test for blood is a good illustration of the subtle individuality of different creatures. If the serum of human blood is injected into a rabbit, it produces a change in the rabbit's blood of a very specific kind. As de Nobele showed in 1902, the serum of that rabbit will give a precipitate with human blood, but not with the blood of other Mammals. Thus if a murderer asserts that the bloodstains on his clothes are due to his having killed a rabbit, not a man, his statement can be tested; and the method has passed into the ordinary practice of medical jurisprudence. The serum for testing with can be kept for months in a dry state (after evaporation in a vacuum) without losing its reliability, and bloodstains that are several months old may be accurately identified. Of course the method has been tested and re-tested hundreds of times, and little improvements in detail have been introduced. It should be noticed that the principle of the method was discovered in relation to milk, and that it was applied in the identification of different kinds of milk and different kinds of flesh before it was applied to blood.

Adaptation

Wherever we look throughout the wide world of animate nature, we find illustrations of particular fitness to particular conditions. The size, the shape, the colour of an organism, the structure of parts in relation to their use and in their relation to other parts—all are *adaptive*. In the same way the characteristic behaviour of the creature in its everyday life, and the internal activities within the body—all are adaptive. And what is true of everyday

activities, where one might attribute some of the effectiveness to practice, is equally true of activities which are only occasional, e.g. those connected with animal courtship and parenthood. Almost every detail of specific structure and specific behaviour may be interpreted as adaptive. This term might simply mean that the structure or function in question is fit, effective, well adjusted, making for the preservation or well-being of the individual or of the species; but in biological usage it has also a theoretical implication —that the detail in question, if it be part of the hereditary constitution or some expression of it, is *the result of a process of evolution.* It was not always as it is now, it has a history behind it, it is a product of the factors of evolution, whatever these may be.

There can be no doubt that no small part of the pleasure we have in the contemplation of living creatures is related to their effective fitness. As Sir J. Burdon Sanderson once said in a lecture, 'the delight and interest with which the forms, colours, and structure of animals and plants fill us is derived from the conscious or unconscious perception by our minds of their *adaptation*—their fitness for the place they are intended to occupy'. He even went so far as to declare his belief that our artistic perception of beauty in nature is in great measure derived from the same source.

In working towards a clear idea of one of the fundamental facts of biology—the adaptiveness of structure and function—it may be useful to consider three other facts—

(1) Effectiveness of response; (2) plasticity; and (3) modifiability.

(1) **Effectiveness of response.**—As we have already seen, effectiveness of response is one of the distinctive peculiarities of living creatures. Many inanimate things

respond to stimuli, but often self-destructively, whereas the living creature's responses tend to self-preservation or to species-preservation. Not that the organism can respond successfully to all stimuli, for instance to a strong current of electricity, for it is not able to live anywhere or anyhow, but only within certain environmental limits. We cannot account for this primary and fundamental power of effective response; it is part of our conception of life. There could have been no organisms at all unless they had possessed something of this power of answering back and yet retaining their integrity. In some degree it must have been part and parcel of the first and simplest organisms, and it has been improved upon ever since.

(2) **Plasticity.**—Another important fact is that living creatures are in different degrees plastic. That is to say, they can adjust their reactions to novel conditions, they are not rigidly stereotyped in their responses. In many cases, even among the simplest organisms, the animal that is up against a difficulty, 'tries' one mode of reaction after another, and may eventually find one which is effective. Professor Jennings reports that the behaviour of certain Infusorians may be compared to a pursuance of 'the method of trial and error'. There are not a few cases of marine animals showing sufficient plasticity to adjust themselves in their own individual lifetime to the very different conditions of fresh water. We see plasticity too when animals are transported from one habitat to another where different habits are required. It is convenient to use the term 'accommodation' for the frequently occurring functional adjustments which organisms are able to make to new conditions. Thus there may be an interest-

ing multiplication of red blood corpuscles in the case of successful human migrants to a lofty plateau,—in South Africa, for instance.

Many unicellular animals are very plastic, and it seems reasonable to suppose that there was a considerable primary plasticity in the early organisms, and that restrictions were placed on this as differentiation progressed. As the body became more and more complex the range of primary plasticity was lessened, but a more specialized secondary plasticity was gained in many cases where organisms lived in environments liable to frequent vicissitudes.

(3) **Modifiability.**—Taking a third step we recognize as a fact of life that organisms often exhibit great modifiability. They can change for their lifetime in response to changes in surroundings or habits. Thus a man's skin may be so thoroughly tanned by exposure to the sun during half a lifetime in the tropics, that it never becomes pale again, even after migration to a far from sunny clime. This change in the skin is a modification: it differs from a temporary adjustment in being permanent, and from a constitutional swarthiness inasmuch as it was impressed from without rather than expressed from within. It is exogenous, not endogenous.

'Modifications' may be defined as changes in the body acquired during an individual lifetime as the direct result of changes in function or in environment, and so transcending the limit of organic elasticity that they persist after the inducing conditions have ceased to operate. Lack of nutrition at a particular stage in development may directly induce an arrest or a dwarfing, with consequences from which there is no possibility of recovery. A particular occupation, such as shoemaking or the old-fashioned weav-

ing, may induce functional changes even in the skeleton, which are there for life.

These modifications are sometimes indifferent, so far as we can judge, as regards the welfare of the organism ; and though they are almost always attempts at effectiveness on the part of the structure affected, they may be prejudicial to the organism as a whole. In the case of a goldfish

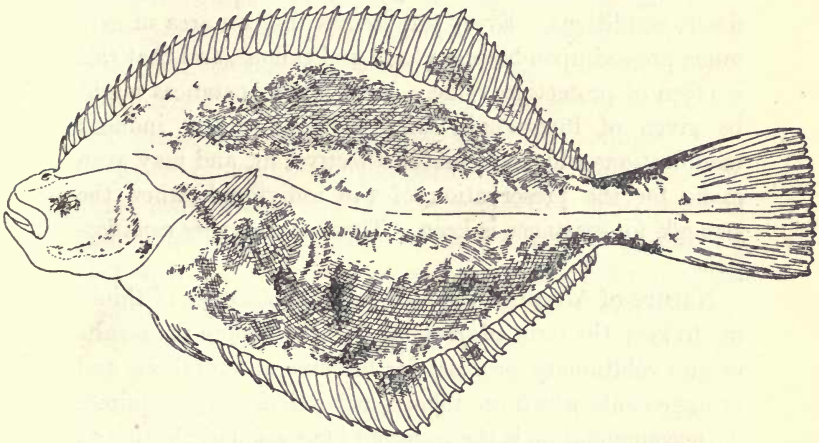

FIG. 80.—Underside of a young flounder, showing pigmentation after exposure to light from beneath. (*After* J. T. Cunningham.)

shut up for years in total darkness, there is degeneration of the eye, which is no doubt a modification on the minus side. Yet the degeneration considered by itself may be regarded as a quite effective response to the abnormal conditions involved. The inflammation that follows an invasion of microbes into the body may lead on to death, but it is none the less an effective response on the part of

the body-guard of phagocytes, and it is often a life-saving one.

In many cases the modifications are markedly beneficial. When a mammal is taken to a colder climate it often acquires a thicker coat of hair, which is obviously advantageous. When a plant is moved from the plain to the plateau it often acquires a thicker epidermis, and Professor MacDougal has furnished numerous illustrations of useful modifications exhibited by plants when transferred to desert conditions. Every one knows that an area of skin much pressed upon becomes hard and callous, and that this is often of protective value. Many other instances might be given of functionally and environmentally induced modifications which are useful, effective, fit, and may even make for the preservation of the individual, when the struggle for existence is keen. These are *adaptive modifications.*

Nature of Adaptations.—It tends to clearness of thinking to keep the term *adaptations* (used to denote the results of an evolutionary process) for features and qualities and arrangements which are inborn, not individually acquired. An accommodation is the transient expression of plasticity; a modification is permanent but individually acquired; an adaptation is racial, the expression of the natural inheritance, not an individual gain or loss. It goes without saying that though these adaptations are potentially implicit in the germinal material—in the fertilized ovum—they cannot be expressed without the appropriate nurture. But this does not bring them in the least within the category of 'acquired characters' or modifications, which result from *changes* in the ordinary nurture. In the same way, it is mere word-splitting to find any difficulty in the fact that ac-

quired adaptive modifications, which are the direct results of changes in the ordinary nurture, could not occur unless the potentiality of them were part of the heritable ' nature '. That goes without saying, but it does not affect the clear distinction between the exogenously induced modification, wrought from without inwards, and the endogenously originating variation which works from within outwards.

Origin of Adaptations.—Like the correlated but larger problem of the origin of species, this is one of the fundamental—still imperfectly answered—questions which the interpreter of animate nature has to face. There are only two main theories in the field—the theory of the direct, and the theory of the indirect origin of adaptations.

(*a*) According to the Lamarckian theory racial adaptations owe their origin to the cumulative inheritance of individual adaptive modifications. But there is as yet a lack of positive evidence in support of this interpretation, plausible as it seems to be. Unless we have experimental evidence of the transmissibility of presently occurring adaptive modifications, we are not justified in using this as an interpretation of results which occurred in the distant past. Too much may be made of the argument that many cases are known where transmission of modifications certainly does *not* occur, but it must be admitted that it is difficult in our present state of knowledge to conceive of any way by which a change acquired by a part of the body can affect the germinal material in a manner so precise and representative that the offspring show a corresponding change in the same direction.

(*b*) The Darwinian theory is that adaptations are due to the selection of those inborn and heritable variations which, by making their possessors better adapted to the

conditions of their life, have some survival value. It is a fact of observation that in many groups of organisms the individuals fluctuate continually in various directions. It is also a fact of observation that some of these variations increase the survival value of their possessors. It is inferred that the cumulative inheritance of these favourable variations, fostered by selection in any of its numerous forms, and helped by the elimination—gradual or sudden—of forms lacking the variations in the fit direction, or having others relatively unfit, may lead to the establishment of new adaptations. The greatest difficulty in this argument is to account for the origin of the fit variations, and this has to be met by the accumulation of observational and experimental data bearing on the origin and nature of variations. It is also necessary to accumulate more facts showing that selective processes—acting directively on fluctuating variations—do really bring about the results ascribed to them.

(*c*) The work of recent years—notably that of Bateson and De Vries—has made it plain that besides the continually occurring 'fluctuating variations,' there are 'discontinuous variations' or 'mutations,' where a new character or group of characters not only appears suddenly, but may come to stay from generation to generation. It cannot be said that we understand the origin of these mutations, in some of which the organism in many of its parts seems suddenly to pass from one position of organic equilibrium to another; but that they do occur is indubitable, and their marked heritability is also certain. Mendel has given at once a demonstration and a rationale of the fact that certain mutations, when once they have arisen, are not likely to be swamped, but are likely to persist,

unless, of course, selection is against them. In horticulture, in particular, artificial selection has operated in great part on mutations. If this interpretation be confirmed and extended, it will not be necessary to lay such a heavy burden on the shoulders of selection. But more facts are urgently needed; and how and under what conditions mutations—whether adaptive or non-adaptive—occur, remains an unsolved problem.

(*d*) In his theory of Germinal Selection, Weismann has elaborated an attractive subsidiary hypothesis. Supposing that the germinal material consists of a complex—a multiplicate—of organ-determining particles (the determinants), he postulates a struggle going on within the arcana of the germ-plasm. Supposing limitations of nutrition within the germ, he pictures an intra-germinal struggle in which the weaker determinants corresponding to any given part will get less food and will become weaker, while the stronger determinants corresponding to the same part will feed better and become stronger. While the external selection of individuals goes on, and is all important, it is being continually backed up by the germinal selection. Thus nothing succeeds like success.

(*e*) Various evolutionists—Profs. Mark Baldwin, H. F. Osborn, and C. Lloyd Morgan—have suggested that although individual adaptive modifications may not be transmissible, they may have indirect importance in evolution, by serving as life-preserving screens until coincident inborn or germinal variations in the same direction have time to develop. As Groos expresses it, in reference to some instinctive activities—Imitation may keep a species afloat until Natural Selection can substitute the life-boat heredity for the life-belt of tradition.

Finally, in thinking over this difficult problem of adaptations, we must remember the importance of the active organism itself. As Professor James Ward has well pointed out, it may seek out and even in part make its environment; it is not only selected, it selects; it acts as well as reacts. And although the details and finesse of this may have been elaborated in the course of selection, the primary potentiality of it is an essential part of the secret of that kind of activity which we call Life.

Illustrations of Adaptations.—The structure of a long bone in a mammal is adapted to give the utmost firmness with the minimum expenditure of material; the unique pollen-basket on the hind legs of worker-bees is adapted to stow away the pollen; the colours and patterns on the wings of leaf-insects are adapted to harmonize with the foliage on which they settle; the parts of flowers are often adapted to ensure that the insect-visitors are dusted with pollen, and thus to secure cross-fertilization; the peacock is adapted to captivate the pea-hen; the mother mammal is adapted for the prolonged pre-natal life of the young; the so-called 'egg-tooth' at the end of a young bird's bill is adapted to the single operation of breaking the egg-shell —and so on throughout the whole of the animate world. It is indeed a mistake to dwell upon signal instances of adaptations, since (apart from degenerative changes in old age, morbid processes, perverted instincts, rudimentary or vestigial structures, and certain 'indifferent' characters which are not known to have any vital significance) almost every detail of structure and function may be regarded as adaptive.

The Mole.—In illustration of adaptive characters let us consider a common animal like the mole, 'the little

B
C
A

gentleman in the velvet coat', who long ago discovered the possibility of a subterranean life for a warm-blooded animal, and disturbed the earthworms in the retreats where they had for so long enjoyed relative immunity. What a bundle of adaptations the creature is! The outturned hand has become a powerful shovel, aided by the presence of an extra bone, the sickle, to the inner side of the thumb; the shoulder-girdle is very strong and the pectoral muscles are those of an athlete; the long muscular sensitive snout, which probes the way, is strengthened by a special bone near the tip; the hind legs remain purely locomotor; the absence of the external trumpet of the ear is an adaptation to the reduction of friction; the minute eyes are well hidden among the hair and thus saved from being rubbed; and there must be some special advantage too in the way the hairs stand out vertically like the pile on velvet. The eye is not well finished, as an instrument-maker might say—the lens in particular being rather half-made and the optic nerve far from well developed—but as the mole is well aware of the difference between light and darkness, and can bite quite deftly at a dangled worm, its eyesight is probably just as good as it needs to be.

Its habits, too, how adaptive they are—the quick hunting close to the surface, the slow deep burrowing below the reach of the frost's fingers in winter, the nest-making below the chief mole-hill or fortress, the making of a special tunnel to the nearest water, and so on. Dr. Ritzema-Bos has verified the observation that moles make a store of earthworms for the winter months, biting their heads off so that they lie inert but not dead. If this were done in the summer months the head would be regrown and the captives would crawl away, but below a certain

temperature the regrowth does not occur, and the decapitated earthworms lie imprisoned without walls.

Fly Trap.—As a fine example let us take Venus's Fly Trap (*Dionœa muscipula*), a member of the Sundew family (Droseraceæ) in which we find a graded series of adaptations to catching and digesting insects. The trap of Dionæa is the much modified leaf. The blade consists of two nearly semicircular halves, united by a strong midrib; the surface is studded with reddish glands, and bears on each side three sensitive jointed hairs; on each margin there are about twenty spikes directed upwards and inwards; the stalk of the leaf is like the handle of a teaspoon with a channelled upper surface and a narrow isthmus where it joins the blade.

When an insect, attracted to the glistening glandular surface, touches one of the upstanding jointed hairs, the halves of the blade begin at once to close in upon one another, the spikes on one side fitting in between those on the other, like the teeth of a rat trap. This happens quickly, but the movement stops before the leaf is completely closed—a fact which Darwin explained ingeniously. Insects of small size, hardly worth catching, escape between the crossed teeth, and the leaf soon re-opens. A larger victim, unable to get through the prison bars, touches the sensitive hairs again and induces a second and more vigorous contraction, which proves fatal. No more effective adaptation could be imagined.

Let us follow the story a step further. When the Venus Fly Trap is *tricked* into closing, it opens again in twenty-four hours. But when it shuts on a big fly it remains with the two lobes pressed against one another for a week or more. The secreting glands are stimulated and pour out

digestive secretion; more and more glands join in; and the two blades bulge outwards partly with the fly and partly with the copious digestive juice. It is interesting to notice in passing, as an instance of the unity of physiological processes that the closing of the Fly Trap leaf is accompanied by an electrical change similar to that associated with every muscular contraction.

Snow Shoes.—One might spend a pleasant lifetime in admiring organic adaptations, and even the most matter-of-fact man must admit that many of them are fine examples of attaining effective results by very simple means. Take, for instance, the 'snow shoes' of the North American Ruffed Grouse (*Bonasa umbellata*). According to Dr. Austin Hobart Clark, these 'snow shoes' develop in winter as two rows of skin 'scutes' on each side of each toe, and they increase the area of the foot by as much again. They remind one a little of the scolloped margins of the toes in a grebe. Their effect is that the bird is able to tread on the lightly-compacted snow without sinking in. It might be interesting to test experimentally whether some artificial stimulus, such as damp ground, would serve to induce the extra integumentary growth at some other season than winter. In regard to the simple mechanism of extra lateral plates, Dr. Clark calls attention to a very interesting point—a quaint structural analogy. A figure of the Ruffed Grouse's toe in winter is very much the same as a figure of the arm of some of the Crinoids or feather-stars from the Deep Sea. Two rows of supplementary plates occur on each side of the median row, and the meaning of the adaptation is to increase the receptive surface on which the shower of minute dead organisms is caught. Thus we have *convergent adaptation* in two creatures almost

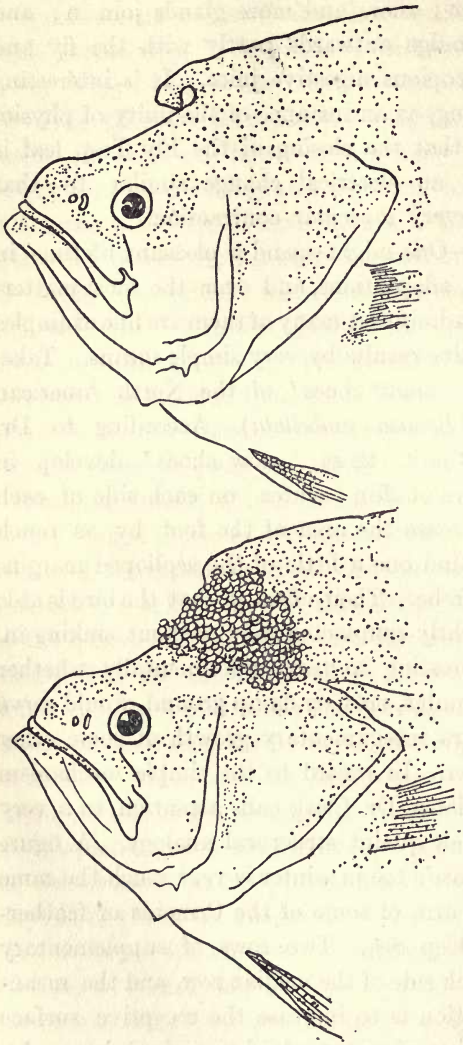

FIG. 82.—Head of Kurtus. (*After* Weber.) The upper figure shows the bony hook. The lower figure shows the bunch of eggs.

literally as far as the poles apart!

Extraordinary Egg-carrying Adaptation in a Fish.—In one of the rivers of New Guinea the explorer, Lorentz, found a remarkable fish, Kurtus gulliveri, whose parental care has been described by Prof. Max Weber. In the mature male a bony process on the back of the skull grows forwards and downwards like a bent little finger, and forms a ring or 'eye'. In this, somehow or other, a wreath of eggs is attached. Each egg has an en-

velope made of coiled filaments; these unwind when the eggs are laid, and are over a hundred in number. The filaments unite into strings, and these into a cylindrical band. Thus the eggs are bound together, forming a twin cluster like a double bunch of onions. The connecting band passes through the bony ring and the male goes about carrying the eggs effectively fastened on the top of his head. The details of the curious attaching filaments which fasten the eggs together have been recently studied by Prof. F. Guitel, who compares them with those of another fish, Clinus argentatus. The adaptation is very remarkable, and one would like to know more in regard to the manner in which the eggs come to be fastened to the bony ring.

Egg-Eating Snake.—A remarkable structural adaptation associated with a remarkable habit is to be seen in the African egg-eating snake, *Dasypeltis scabra*, a weak-bodied creature less than a yard in length which is able to swallow birds' eggs three times the diameter of the thickest part of its body. The jaws are almost toothless, but a few posterior teeth are present which serve to grip the egg. There is the usual alternate gripping and muscular engulfing, and the intact egg slips into the gullet. It is then met by the sharp points of the inferior spines of a number of the vertebræ, which project into the gullet, and cut the egg-shells. It is said that they are actually tipped with enamel. The result of the structural adaptation is that none of the precious egg is wasted. Mr. Ditmars, the curator of reptiles at the Zoological Park in New York, who has a wide experience of living snakes, says that the empty egg-shells are always returned, and that this habit is quite unique. Many snakes eat eggs, but they break the shells in a rough and ready

way by pressing their throats against the ground, and in these cases the fragments of shell pass down into the stomach and are dissolved away. One would like to know more about an Indian snake, *Elachistodon westermanni*, which has a structural peculiarity like that seen in *Dasypeltis*, but there does not seem to be any certainty as to how it uses it. As the Indian snake belongs to a different group the occurrence of a similar peculiarity of structure is very interesting, and the interest would be enhanced if there is also an egg-eating habit.

Aristotle's Lantern.—Commanding our admiration as a piece of mechanism which can discharge several different functions is 'Aristotle's lantern' which surrounds the beginning of the food-canal in the 'regular' sea-urchins. Aristotle saw it more than two thousand years ago—a neat contrivance with five continually growing teeth in five sockets which are united by 'braces' and 'compasses' and swayed about by strong muscles attached to five 'standards' on the test. It is capable of rhythmic movement which helps in mastication, in boring, in respiration, and perhaps in keeping up a certain turgescence in various internal cavities of the body of the sea-urchin. But perhaps the most remarkable thing about the lantern is that discovered by Dr. J. F. Gemmill: it is an organ of locomotion in certain conditions, and acts as an auxiliary to the suctorial tube-feet and the spines. The sea-urchin can stumble along on the tips of its teeth—which seems a most extraordinary statement to make. In each step the urchin is raised on the tips of the teeth and a forward impulse is given, (*a*) by strong pushing or poling on the part of the lantern, (*b*) by similar but usually less effective pushing on the part of the spines, and (*c*) after a certain stage,

by the influence of gravity. The lantern is then retracted and the teeth swing forward into position for initiating a new lurch.

Eyes that shine at Night.—Every one knows the gleam of a cat's eyes when a light catches them in the darkness. This appears to be due to reflection from a layer behind the retina called the choroid tapetum. This layer includes numerous flat cells packed with crystalloid bodies which act like a mirror. In some beetles and moths the eyes shine like rubies when they are obliquely illumined at night. Prof. Bugnion has recently studied the eyes of one of the hawk-moths, Sphinx euphorbiæ, and finds that the retina is very thick and infiltrated with a rose-coloured pigment, 'erythropsin.' Part of the retina forms a tapetum, and the reflection is due to a network of silvery air-tubes or tracheæ, helped to some extent by movement of the retinal pigment. It is probable that the reflection of the light rays from the tapetum is advantageous, since the visual cells are thus affected twice instead of once.

The Chick's Egg-Tooth.—An adaptation that gives one pause is the 'egg-tooth' found at the tip of the bill in many young birds, and used by them to break a way through the imprisoning egg-shell. It is a hard thickening of horn and lime at the tip of the bill, and since it develops before the horny ensheathment of the beak it may be a residue of a very ancient scaly armature in Reptilian ancestors of birds. Be this as it may, the instrument is an effective one, and it is used only once! What happens is this: the young bird ready to be hatched thrusts its beak into the air-chamber that forms at the broad end of the egg; air rushes down the nostrils and fills the lungs for the first

time ; in the exhilaration of this first breath the unhatched bird knocks vigorously at the shell and breaks open the prison doors. After a few days, in most cases, the egg-tooth, having done its work, falls off—a well-adapted instrument that functions only once.

But there is a further detail which is of much interest. The bill and its egg-tooth are only the instruments, what about the musculature which works these ? Professor Franz Keibel has inquired into this in the case of the unhatched chick and duckling. He finds that the work is done by a muscle called the *musculus complexus*, and that it is very markedly hypertrophied for some time before hatching. On the tenth day after hatching, it shows no peculiarity. Here then we have a signal instance of the way in which development proceeds *as if it were working with a purpose.* How comes that *musculus complexus* to be temporarily exaggerated in strength, in relation to the breaking of the egg-shell—an action which only occurs once in each generation ?

Similar egg-openers are well known among insects. Thus, in the embryo of a Bug, *Palomena dissimilis*, described by Heymons, there is on the top of the head a T-shaped chitinous ridge with a minute apical tooth. This curious apparatus is used to force open the lid of the egg. When the young insect creeps out of the egg-envelope, it moults and loses its egg-opener. Thus we have another example of a structure which functions only once in a life-time.

Before Birth.—There is something very striking in adaptations before birth—in fitnesses which occur while the creature is still at its *vita minima* and very inert. Mr. T. Southwell finds a good example in the young of the saw-fish (*Pristis cuspidatus*). He dissected a large female

fifteen and a half feet long, and found twenty-three embryos in the oviducts. As each of these was about fourteen inches long, including the toothed saw of five inches, one naturally becomes curious as to the relation of the weapon to the wall of the oviduct. Mr. Southwell found that the teeth of the saw were 'entirely covered by a transparent cartilaginous tissue, which of necessity must disappear later.'

FIG. 83.—Mermaid's Purse, or horny egg-case of dogfish, with attaching tendrils.

Every one who lives on the coast is familiar with the egg-cases of skate and dogfish, the so-called mermaid's purses. These are quadrangular sacs with a long tendril at each of the corners; they are made of jets or fluid filaments of keratin which are secreted by a gland in the oviduct and coalesce into a flexible egg-case. There are no living cells in the egg-case itself; it encloses the large egg-cell laden with yolk and floating in albumen or white of egg. When the egg is liberated from the mother-fish, the tendrils writhe automatically in the water and twine round sea-weed on the floor of the sea in the shallow-water area. Thus the eggs are saved from being smothered in the drifting mud, and the developing embryos within are gently rocked, and thus the better aerated, by movements in the water. But how is the embryo to escape from its

closed cradle? It appears that at the time of hatching there is a secretion from the embryo which acts as a solvent on a weak seam at one end of the mermaid's purse. The end gapes, and the miniature skate or dogfish works its way out. Now it is interesting to find a parallel adaptation in the far-separated bony fishes, where there is no egg-shell, but only a firm shell-membrane. Both in the trout (*Trutta fario*) and in the goldfish (*Carassius auratus*) Wintrebert has found that the unicellular glands of the embryo's skin secrete before hatching a 'peri-embryonic fluid' which has a digestive action on the shell-membrane. It becomes more delicate and finally almost like wet paper, being readily broken without any voluntary movement on the part of the embryo-fish.

A Difficult Case.—It must be admitted that some adaptations are so remarkable that it is very difficult to resist the intellectual temptation of supposing that they arose in direct relation to the peculiar conditions. Let us state the case in the words of a naturalist who believes that we are warranted in making the supposition which seems to us at present illegitimate.

'There is a fish', Mr. J. T. Cunningham writes, 'which has its eyes in a very remarkable condition. Spectacles for human eyes are sometimes made, in which the upper half has a curvature different from that of the lower. The fish to which I refer, the *Anableps*, which lives in the estuaries of Brazil and Guiana, does not wear spectacles, but actually has its eyes made in two parts, the upper half of the lens having a different curvature from that of the lower. The pupil is also divided into two by prolongations from the iris. This fish is in the habit of swimming at the surface with its eyes half out of water; the upper

half of the eye is adapted for vision in air; the lower half for vision under water. Now, however various the individual variations in fishes' eyes, there is no evidence that variations, which could by selection give rise to this curious condition, occur in other species of fish. It seems to me that we have no reason to suppose that the required variations ever occurred until the ancestors of *Anableps* took to swimming with their eyes half out of water. A similar argument applies to many other cases of special adaptation, and the logical conclusion is that the habits and conditions determined the modification'.

This is admirably put and the difficulty is great; but it should be noted that there has been very little investigation of the variations in the eyes of fishes, that we have very little warrant for supposing that such a remarkable change in the lens could arise as the direct result of the peculiar habits and conditions, and third, that it is possible that the fish took to its peculiar mode of surface swimming because its peculiar eyes were suited to that habit.

Similar Structures put to Diverse Uses.—Our idea of adaptability may be enriched if we consider how the same structure is utilized for all sorts of different results. Let us take a series of glands, for instance, which, though not quite homologous, are in a general way similar—pouring a secreted juice into the mouth cavity. In a leech the secretion keeps the ingested blood from coagulating, so that it remains more usable in the crop; in some marine Gasteropods it contains dilute sulphuric acid which seems to be of use in dissolving the carbonate of lime, say in a starfish's armour; in some cuttlefishes, such as *Eledone moschata*, it has a rapid paralyzing effect on the nervous system of crabs which form an important part of the diet;

in the sea-swift (*Collocallia*) it forms, when it solidifies against the rock, the well-known 'edible bird's nest'; in the ant-eater it moistens the worm-like insect-catching tongue; and in the great majority of cases from snail to man it contains a diastatic ferment which changes the solid starch of the food into fluid and diffusible sugar. We have given only a few instances of the extraordinary gamut of function exhibited by glands which might all be called 'salivary'.

Some Functional Adaptations.—One of the most important of functional adaptations is that by which birds and mammals (the so-called warm-blooded animals) are able to keep the temperature of the body approximately constant. A healthy man may 'feel very warm' or 'feel very cold', but his temperature varies very little from the normal 37° C. or 98·4° F., year in, year out, or from the Poles to Equator. A bird may fly in a very short time, perhaps in a couple of days, from North Africa to within the Arctic circle, but there is no reason to believe that its body-temperature will change at all. This keeping of a constant temperature is restricted to Birds and Mammals, which are therefore called homoiothermal or stenothermal.

The problem is to regulate the production of heat to the loss of heat, and it is solved in Birds and Mammals by a special adaptation of the nervous system. Most of the heat that is lost from the body is lost from the skin; as the skin gets cold nervous messages travel inwards to the central nervous system, and reflex answers come out commanding the skin blood-vessels to contract and commanding the muscles to produce more heat. The contracting of the skin blood-vessels lessens the flow in the skin, and

thus lessens the loss, while the 'toning up' of the muscles increases the supply. Shivering is the attempt of the muscles to 'tone up'.

It is very interesting to consider some of the exceptions. In the case of many young birds and mammals, a short exposure to cold is fatal, because the thermotaxis or heat-regulating arrangement has not yet been established. In the egg-laying Mammals—the duckmole and the spiny ant-eater—there is an extraordinary range of temperature, which is what one might expect in relative primitive types with a good deal of the reptile about them still. In hibernating Mammals like the hedgehog and the dormouse, the heat-regulating arrangement has gone out of gear, and the animal becomes colder and colder as the external temperature falls.

But the most familiar exception—all too familiar—is fever, which occurs when the fine balancing adjustment has been put out of gear by poisoning, or when the conditions of heat-production or heat-loss are such that the normal arrangements cannot cope with them. There may be too much production of heat as in pneumonia, or too little loss as in typhoid. If the temperature of the blood exceed a certain limit, the nerve-cells are fatally injured as in 'sunstroke'. It must be noted, as Professor Fraser Harris points out, that while fever (pyrexia) is the upsetting of thermotaxis, the disturbance of the beautiful thermal balance, it is not now regarded as a wholly bad thing to be reduced at any cost. In a luminous article he says :—

'Fever is to-day regarded by physicians in a totally different light from what it was even a few years ago—in itself a wholly bad thing to be reduced at any cost. The increased heat-production is looked on as a reaction on the

part of the living cells to the noxious stimulus of the micro-organism or its soluble poison, a response of a protective nature rather than of any other kind. Hence the indiscriminate lowering of the temperature by drugs (antipyretics) is not now nearly so common as it used to be. It is recognized as possible that the increase of heat (fever) may be evidence of sufficient vitality on the part of the living protoplasm to withstand the assaults of the infective agents, the increased heat being the biophysical response to the micro-organic insults'.

It is a familiar fact that living at a high altitude puts a strain on the heart, which has more work to do. Some people cannot live above a certain level. In this connection it is interesting to refer to a careful comparison made by Strohl of ptarmigan from high altitudes and willow-grouse from the plains. He found that in the ptarmigan, even in the young bird, the right ventricle of the heart is very distinctly stronger than in the willow-grouse. This seems clearly to indicate a specific adaptation of the heart to the difference of habitat.

One of the subtlest of adaptations is immunity to the poison of some enemy. Thus in some parts of Europe there is an intrepid little Rodent, the lerot (*Eliomys nitela*), a relative of the dormouse, which has pluck enough to fight with vipers, and G. Billard has shown that it is immune to their venom. A similar immunity to snake poison is possessed by the mongoose, the pig, and the hedgehog. And as to the last, Dr. Strubell has shown that it is relatively immune to the toxins of diphtheria and tetanus. It is likely enough that the hedgehog has a special antitoxin which counteracts the toxin of snakes, but it is difficult to understand what is meant by its indifference to

diphtheria and tetanus. Perhaps it is lacking in appropriate physiological susceptibility to these diseases, without having any special anti-toxin against them.

It is in human nature to find satisfaction in fitness, and not for practical reasons only, but because when things 'fit' we feel convinced of their rationality. It gave reassurance to the old lady to discover that so many great rivers flowed past so many great towns, for that was as it should be; and it has often been pointed out that the length of the day is physiologically well adapted to the average man's capacity for work! In his famous Bridgewater Treatise (1834) Whewell showed in detail how the constitution of the world—from the length of the year to the magnitude of the ocean, from the properties of water to those of the atmosphere—was admirably fitted for the support of the vegetable and animal life which the earth contains. And from of old it has been the delight of naturalists to discover the adaptations with which organic nature abounds.

Some of those which we have been considering seem almost magical in their intricacy and subtlety; but most intellectual combatants admit that Darwinism has supplied a partially adequate formula for their coming-to-be. The organism is always varying, always experimenting—and these variations or experiments (which we are still only beginning to study) form the raw materials of organic progress. They are subjected to Nature's sifting and singling, pruning and favouring ('Natural Selection in the Struggle for Existence'), and the result is the establishment of the adaptations we justly admire. The magicalness has gone; the rationality is more apparent than ever. And if we can more or less clearly see how individual

adaptations may have been wrought out, this does not lessen the wonder of that variability that supplies the raw material.

Colour Adaptations.—There is great wealth of colouring in the animal kingdom. Humming-birds, tropical fishes, mollusc-shells, butterflies, starfishes, and sea-anemones immediately occur to one, and it would be easy to mention a hundred gorgeous examples. The colour is partly due to pigmentary substances made by the animals; partly to the physical structure of the surface—e.g. the occurrence of thin lamellæ or very delicate sculpturings which cause interference of light; and partly to a combination of pigment and some peculiar physical structure. The redness of the blood is due to a pigment—hæmoglobin; the iridescence of many a shell is wholly due to the physical structure; the coloration of a peacock's feather is due to a combination of the two kinds.

It may be noted, for the sake of completeness, that some animals owe their colour to other organisms which live in association or partnership with them. Thus the common green Hydra is green because of minute partner Algæ which live within its transparent cells. And at the other end of the scale we find that the shaggy S. American tree-sloth (*Bradypus*) is greenish, because of minute Algæ that, strangely enough, find a living on its rough hair.

In the simple marine worm, *Convoluta roscoffensis*, so carefully studied by Professors Keeble and Gamble, the green colour is due to a unicellular Alga which lives in partnership with the cells of the worm's body. The newly-hatched worm is colourless, and has to be infected from the sea-water or from the egg-capsules on which the Alga habitually settles. A curious point is that the green cells taken

from an adult Convoluta cannot live independently, and yet we know that the Alga lives freely in the water. The investigators have shown that this is due to the fact that in association with the worm the Algoid cells suffer degeneration of their nucleus. Thus the Alga becomes dependent on its partner, which in turn becomes dependent on it, for in course of time the Convoluta ceases to take in food, relying upon the materials worked-up by its partner.

It should also be noticed that some animals owe their colour directly to their food. Thus some caterpillars are green because of the chlorophyll of the leaves they eat; and some sea-slugs appear to borrow the pigment of the sponges they browse on.

If we rank whiteness as a colour, it must be regarded as structural, for it is usually due either to minute gas-bubbles in the cells, as in white hair and feathers, or to minute crystalline spangles, as in many silvery fishes. According to Metschnikoff, the whitening of hairs and feathers in winter is in certain cases due to the activity of phagocytes, which transport the pigment into the skin. He made observations on the Mountain Hare (*Lepus variabilis*), on the Willow Grouse (*Lagopus albus*), on the ptarmigan (*Lagopus alpinus*), and on a hen which began to turn white, and found the so-called 'chromophagous' cells actively at work.

As to the form in which pigment occurs in animals, there is great diversity. It may be precipitated in a non-living layer, like the zoonerythrin in the cuticle of crabs and lobsters, shrimps and prawns; it may be in the form of minute granules in a thick fluid, as in the sepia of cuttle-fishes; it may be a solid mass, like the cochineal of coccus insects; it may be in the cells of the blood, as in Verte-

brates, or in the fluid of the blood, as in earthworms; it may be in the form of coloured spicules or calcareous deposits, as in Alcyonarian corals; it may be in special cells which often show considerable activity—the chromatophores (see Fig. 87).

Primary Significance of Pigments.—There have been relatively few important inquiries into the physiological significance of pigments, which is a very difficult problem; but it may be said that some pigmented substances are of the nature of waste-products, like the green guanin in a lobster's kidney, or the sulphur-yellow in the wings of some butterflies, or the sepia of the cuttlefish; that others are of the nature of reserve products, like the carmine which accumulates in the body of the female cochineal insect; that others are simply indifferent by-products of the metabolism. That pigments need not be useful as such is quite plain when we remember that the internal organs of many animals are brightly coloured. Thus the gonads of some starfishes and sea-cucumbers are brilliant.

Primary Significance of Structural Coloration.—The cross bars, the concentric lines, the zoned structure, and the superposition of very thin lamellæ produce interference colours, but what is their primary significance? The answer must be, that they are the ripple-marks of growth; they are expressions of the fact that growth is rhythmic, not continuous. The familiar concentric lines on the stem of a tree express the difference between the summer and the winter wood; the lines on the surface of a shell are indices of periods of growth punctuated by times of rest.

As a further illustration of the idea towards which we are groping—that many structural features are just, as it were,

the ripple-marks of internal tides (periodic or rhythmical changes in metabolism and growth), we may refer to the suggestive observations of Riddle (1908) on fault-bars in feathers. Fault-bars are weak areas interrupting the fundamental barring of the feather, and they appear to be due to malnutrition or to defective nutrition. They may be produced by feeding the birds with Sudan III, by unwholesome conditions, or by using amyl nitrite to reduce blood-pressure. They are usually laid down at night, when the blood-pressure is normally lower than during the day. The structurally weakened areas tend to be less pigmented, and it has been shown that the production of the dark (melanin) pigment in feathers may show quantitative fluctuations corresponding to changes in the available food supply.

'The reduced nutrition, brought about daily by the minimum blood-pressure; the disadvantageous position, in relation to the blood, of the pigment and barbule elements of the feather; together with the very rapid rate at which feathers grow, furnish the complex of conditions which bring unfailingly into existence a fault-bar, and to a more or less appreciable extent a light fundamental bar, at perfectly regular intervals in the entire length of every feather formation.'

This is of very great importance, for we are here beginning to see how an alternation in the rhythm of internal processes may have far-reaching external results—which afford much more than raw material for Selection to work on.

Physiologically useful Pigments.—Having recognized that pigments occur in an organism as waste-products, reserve-products, or by-products, and that there need not

be primarily any virtue in their *colour*, we hasten to point out that they are often of very great physiological value, and that their colour, as well as their chemical composition, may be of vital importance. Speaking metaphorically, we may say that this has been one of the methods of evolution to catch up some quality which is present for some deep constitutional reason, and give it a novel secondary value—often life-saving. (*a*) The whole world of life depends on the green pigment, chlorophyll, which is characteristic of plants, for it is a condition of the photosynthesis or upbuilding of sugar and other organic compounds in the leaves that the sunlight should reach the living matter through the screen of chlorophyll. (*b*) The red pigment, hæmoglobin, which made its first appearance (as far as we can judge) in some Ribbon-worms or Nemerteans, was also a physiological discovery of the highest importance, for its capacity of entering into a loose union with oxygen, and thus becoming an oxygen-carrier, must have greatly facilitated and improved the function of respiration. Along with hæmoglobin, which occurs in all Vertebrates and in some Invertebrates (such as some Nemerteans and Annelids), there have to be ranked a number of other respiratory pigments. One of the commonest of these among Invertebrate animals is hæmocyanin, of a faint bluish colour. In addition to transporting oxygen, some pigments are of great value in storing it within the body, e.g. in the muscles. (*c*) Another use of pigment is in connexion with vision, for the dark pigments of the retina are continually undergoing chemical change, and they often show remarkable alterations in position. In the peculiar condition known as night-blindness there appears to be a lack of the normal ' visual purple ' in the retina.

(*d*) Another direct utility may be recognized in the pigmentation of the skin in various animals. Thus the dark skin of some animals from very warm countries and the whiteness of some animals from very cold countries may have a direct physiological value to its possessor. It appears that the dark insoluble melanin pigments, as in the crow and negro, are protective against the ultra-violet rays of sunlight. A remarkable fact was observed by Engelmann in regard to the peculiar restless Algæ known as Oscillatoria. He found that in red light they had a green colour, and in green light a red colour—in both cases the physiologically best colour.

Protective Value of Coloration.—Some of the finest instances of adaptation are seen in the way animals resemble their habitual environment. Shape and pose sometimes conspire with coloration to give the animal a mantle of invisibility. Referring for details to books on animal coloration by Professor E. B. Poulton and Mr. F. E. Beddard, we wish to give a few representative illustrations. Many desert animals have an isabelline or sandy coloration that renders them very inconspicuous; the fennec fox and the gerbille, the sand-grouse and the horned viper are good examples. Green snakes are difficult to detect on the trees and the common shore-crab, whose colour is variable, often harmonizes to a nicety with the background of the rock-pool. In many birds and mammals, as Thayer has well shown, a very perfect garment of invisibility is attained in a very simple way—by having the under surface of the body rather lighter than the upper surface.

The protectiveness is heightened when the animal is like something else, not in colour merely, but in form; and there is no better example than the Javanese butterfly

Kallima, which is conspicuously coloured on the upper surface, but becomes like a withered leaf when it folds its wings together and exposes the brown under surface (Fig. 11). As we have noted, the nervures on the wings look like the veins on a leaf, and the suggestion of a midrib increases the resemblance. Spots on the wings look like holes on the leaf, and so on. In fact, perfection is attained by the combination of a number of items. Even the fact that the coloration of the under surface and the position of spots may vary a little is perhaps advantageous, since the butterfly has thus a general resemblance to different kinds and states of withered leaves.

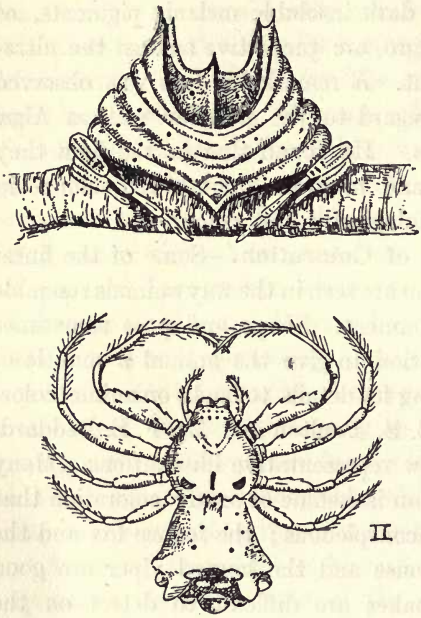

FIG. 85.—Two spiders: I. Cærostris mitralis like a knot on a twig; and II, Ornithoscatoides decipiens, like a bird's dropping. (*After* Vinson and Pickard-Cambridge.)

Protective colour-resemblance is seen at its best in cases where the animal can adjust itself to the coloration of the surface on which it is resting; and there is no better illustration than that of plaice and other flat-fishes, which are

able in a short time to alter the disposition of their pigment cells so as to become part and parcel of their background. The figures we have given show the nicety of the harmonious adjustment (Fig. 10).

Great care must be exercised in ascribing protective value to the colour-resemblance between an animal and something else, and each case must be judged on its own merits. It must be made clear, for instance, that the resemblance which conceals the creature from us is equally effective in concealing it from its natural enemies. The desert insect does not escape the desert lizard, and the green insect on the twig is unhesitatingly picked off by the sharp-eyed bird who has made that its business. Some creatures, like sea-slugs, which are often very harmonious with their surroundings, are seldom eaten by anything.

It is satisfactory, then, that there are some definite observations proving the protective value in particular cases. With silk threads Cesnola tethered forty-five green praying mantises

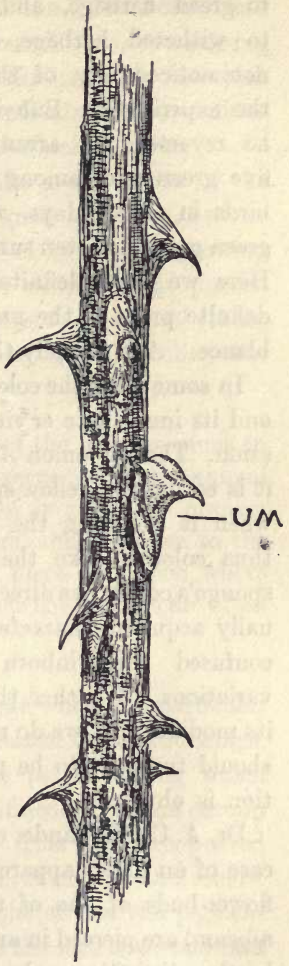

FIG. 86.—A Venezuelan insect, Umbronia spinosa, with a marked resemblance to a prickle on the twig on which it (UM) is seated. From a specimen.

to green herbage, and sixty-five of the brown variety to withered herbage, and found that the birds had not noticed any of them within the seventeen days of the experiment. But it was quite another story when he reversed the arrangement. When he put twenty-five green ones among brown herbage, all were killed by birds in eleven days, while of forty-five brown ones on green grass, only ten survived at the end of seventeen days. Here we have definite proof of a selective death-rate, definite proof of the protective value of the colour-resemblance. And happily the case does not stand alone.

In some cases the colour-resemblance between the animal and its immediate environment has a very simple explanation. The sea-lemon *Archidoris tuberculata* is yellow when it is eating the yellow sponge *Dendoryx incrustans* and red when it is eating the red *Esperella œgagrophila*. It is thus coloured like the sponge it is browsing on; the sponge's colour has directly affected it. This is an individually acquired character—a modification, and not to be confused with inborn colour-changes—which we call variations. Whether the sea-slug is protected or not by its modification, we do not know, but the point is that, if it should turn out to be protected, the origin of the protection is obvious.

Dr. A. Ch. Hollande, of Nancy, reports a very interesting case of an insect apparently protected by its meals. The flower-buds of one of the mountain-mulleins (*Verbascum nigrum*) are pierced in autumn by the larva of a Curculionid beetle called *Cionus olens*, which feeds on the violet hairs of the stamens. The violet vegetable pigment (anthocyan) eaten by the grub passes down the food-canal, and, in the usual way, into the blood, where, however, it has an

uncoloured form. It is carried to the fatty bodies and accumulates there in numberless granulations, re-assuming the violet colour, which shines through the brownish integment and makes the grub effectively harmonious with the colour of the stamens amid which it works.

In the case of the Tree-Sloth, the green colour of the hair is due to Algæ which might grow elsewhere, and as there are other instances of plants of low degree growing on living hairs, the Sloth's case is no particular puzzle. In Baron Albert von Sack's *Voyage to Surinam* (1810) there is a surprisingly early reference to this peculiar case of protective resemblance.

'The colour and even the shape of the hair are much in appearance like withered moss, and serve to hide the animal in the trees, but particularly when it gets that orange-coloured spot between the shoulders, and lies close to the tree; it looks then exactly like a piece of branch where the rest has been broken off, by which the hunters are often deceived'.

Account must also be taken of cases where the particular colour depends physiologically on that of the surroundings. Some caterpillars have a sensitive period during which their colour or that of the pupæ is influenced, within certain limits, by the surrounding colour. This has been proved experimentally by Professor Poulton, Schröder, and others. How the colour of the reflected light affects the pigmentation of the animal is obscure, but the fact is certain in a few cases, and it is to be associated with the fact, also proved in a few cases, that the mortality among pupæ is in part dependent on the degree of their inconspicuousness against certain backgrounds. It is stated that the colour

of a shore-crab is directly influenced, while the shell is being formed after a moult, by the dominant colour of the immediate environment.

There can be no doubt that certain colour-reactions which follow reflexly and necessarily often look as if they

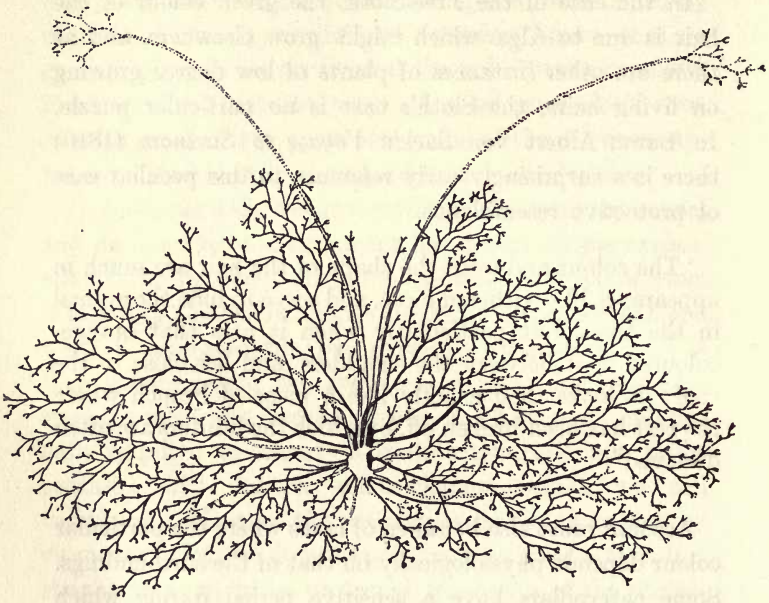

FIG. 87.—Much branched chromatophore of a prawn, Praunus flexuoxus. (*After* Degner.) The pigment flows out along the root-like branches or contracts centripetally. The chromatophore seems to arise from a combination of cells—a syncytium.

should be advantageous, but it is difficult to give direct proof of this. One of the prawns, *Palæmon treillianus* studied by Fröhlich (1910) is blue or green by day, when its red chromatophores are strongly contracted, and reddish-brown by night, when the red chromatophores expand. When one is put into a white porcelain vessel it becomes

milky and translucent; the chromatophores contract greatly, and there is an unexplained turbidity in the carapace. When it is put into a glass vessel and that placed on a mirror, it becomes transparent, the maximum contraction of chromatophores occurs. It is easy to imagine conditions where this milkiness or this transparency would be very useful. On the other hand, we read that an individual forced to jump loses its transparency, which does not sound so adaptive.

Professors Gamble and Keeble have demonstrated a remarkable plasticity in the coloration of the Æsop-prawn (*Hippolyte varians*), which may be red, yellow, blue, orange, olive, violet, brown, green, and other colours. It is born without a bias, and it takes on the hue of its environment, both when young and adult. If it is put in an aquarium the sides and floor of which are lined with coloured paper, it takes on the colour; and it will change from one colour to another. It seems to have more plasticity in its coloration than it can possibly need, but it can make itself invisible among the bright colours of seaweed.

In the Æsop-prawn the colour changes periodically with the nervous state of the animal, according as it is sleepy or wakeful. We venture to quote Professor Gamble's fine description (*The Animal World*, p. 140):

'The wakeful hours of Hippolyte are hours of expansion The red and yellow pigments flow out in myriads of stars or pigment-cells; and according to the nature of the background, so is the mixture of the pigments compounded to form a close reproduction both of its colour and its pattern: brown on brown weed, green on Ulva or sea-grass, red on the red Algæ, speckled on the filmy ones. A sweep of a shrimp net detaches a battalion of these sleeping prawns,

and if we turn the motley into a dish and give a choice of seaweed, each variety after its kind will select the one with which it agrees in colour, and vanish. At nightfall, Hippolyte, of whatever colour, changes to a transparent azure blue; its stolidity gives place to a nervous restlessness; at the least tremor it leaps violently and often swims actively from one food-plant to another. This blue fit lasts till daybreak, and is then succeeded by the prawn's diurnal tint. Thus the colour of an animal may express a nervous rhythm'.

In many cases, both among plants and animals, the range of colour exhibited by one and the same organism is very striking, but it has sometimes a very simple explanation. There is a colourless 'chromogen' substance, or 'mother of pigment', which takes on different colours according to the amount of oxidation to which it is subjected under the action of a ferment. One of the common colour-evoking ferments is called tyrosinase. The different colours in cases of this sort simply correspond to different rates or rhythms; and it is easy to understand how this or that punctuation might be fixed by Natural Selection.

The common sea-slater, *Lygia oceanica*, has numerous much-branched black or dark brown chromatophores in its epidermis, which make it inconspicuous against a dark background of rock. Tait has shown (1910) that if the creature is exposed to light in a black-painted dish, it remains dark, but that if it is exposed in a white dish it becomes lighter in colour and more transparent, so that eventually the heart can be seen beating through the skin. This change is due to a retraction of the black chromatophores, which also leaves certain white chromatophores more in evidence. When the eyes are painted over with

lampblack, no change follows the transference to a white surface, which shows that the external colour first affects the eyes, then the central nervous system, and then the pigment-cells in the skin.

It is very instructive to compare the juvenile and the adult coloration. In many young mammals and birds, as Dr. Chalmers Mitchell has well shown in his *Childhood of Animals*, the coloration requires little more than a physiological interpretation. The pigments are by-products of the metabolism; they are laid down in agreement with the particulate character of the skin, or they may express the rhythms of growth—being laid down, for instance, in concentric lines and cross-bars. If this primitive coloration is not disadvantageous, it will, of course be tolerated, but the point is, that it does not require any special utilitarian explanation. It may, indeed, be quite useful—thus the spottiness of some young mammals makes them very inconspicuous. As the young creature grows its coloration changes. The spots may unite into stripes or bands, or they may be blurred into a monotone. Or it may be that a new pattern replaces the primitive one; sometimes of ruptive vividness, so that the natural outlines of the animal are broken up protectively; sometimes of startling and impressive brilliance, such as we see in certain sex-decorations. It is when we pass to the secondary coloration, analysed out of the primary as aniline dyes from the coal-tar residue, that we feel the need of special utilitarian or selectionist interpretations. And they are not lacking!

Warning Coloration.—A third use of coloration, first expounded by Alfred Russel Wallace, is as an advertisement on the part of animals that are unpalatable or offensive

or in some way safe. 'They require', as Wallace said, 'some signal or danger flag, which shall serve as a warning to would-be enemies not to attack them, and they have usually obtained this in the form of conspicuous or brilliant coloration, very distinct from the protective tints of the defenceless animals allied to them'. It is satisfactory that this interpretation has been justified by a number of experiments, which go to show that hungry animals, once or twice duped by having conspicuous unpalatable caterpillars and the like given to them to eat, soon learn by experience and are aided in this by the impressiveness of the colouring. Even in fishes, whose cerebrum remains at a very low level, an association between colour and a gustatory experience may be established and retained. It has to be admitted, however, that in many cases the experiment of offering conspicuous unpalatable caterpillars and the like to hungry animals has failed to confirm the theory of warning coloration, so that each case has to be judged on its own merits. In some cases there appears to be truth in the interesting suggestion of Eisig, that very abundant deposition of a waste-matter pigment may render an animal at once unpalatable *and* conspicuous.

This much seems certain, that numerous noxious or aggressive types, such as wasps, coral snakes, and skunks, are conspicuously coloured. A familiar and plausible illustration may be found in the common salamander (*Salamandra maculosa*), which is conspicuous in its black and yellow livery and has a very glandular skin—the secretion of which is perhaps noxious.

Recognition-Marks and Guide-Marks.—A fourth use of coloration is to aid animals in the rapid recognition of their kith and kin, and in the rapid execution of

precise movements, such as placing food in the nestling's mouth. It was Alfred Russel Wallace who first expounded the theory of recognition colours, bringing forward instances, especially from among deer, antelopes, birds, and insects, of striking patches of colour which may be plausibly interpreted as facilitating rapid recognition. One of the best instances is also the most familiar—the rabbit's upturned white tail. When they are feeding in the twilight and are suddenly alarmed, safety may depend on the rapidity with which they reach the burrows. Hesitation may be quite fatal, and it does not seem far-fetched to suppose that 'the white, upturned tails of those in front serve as guides and signals to those more remote from home, to the young and the feeble'. The white stripe above the springbok's tail, which is nearly concealed when the animal is at rest, but very prominent when it starts to run, is probably another good instance.

In Mr. W. P. Pycraft's fine *History of Birds*, which is a rich treasure-house for students of adaptations, attention is called to the bright colours sometimes seen around or in the mouth of nestlings; and the interpretation is offered that they serve as a guide to the parents when feeding the young. The inside of the mouth is diversely coloured, e.g. bright yellow, as in the thrush, and purplish-red, as in the chaffinch, while in the Bearded Titmouse it is of 'a bright cornelian red, surrounded by a band of yellow, and relieved by a double row of white, glistening, tooth-like conical processes'. It seems that the most elaborate oral decorations, as in the Gouldian Weaver-finch (*Poëphila gouldii*), are found in young birds which are hatched in places where there is but little light. Chun has noted that in this bird the brilliant bodies at the angles of the mouth of the nestling

reflect the light like mirrors and are effective guide-marks.

Attractive Coloration.—A fifth use of coloration is to add to the *ensemble* of attractiveness which one sex has for the other, and which, by stimulating sexual interest and increasing sexual excitement, makes pairing more effective. It is usually the male who is the more decorative and brilliant, but there are exceptional cases of the reverse. The tail of the peacock is a masterpiece in this kind of coloration, and the decorativeness of male Birds of Paradise and Lyre-Birds and Pheasants is hardly less transcendent. The habits of Bower-birds and some other birds which collect brightly-coloured or shining objects, suggest that an appreciation of colour, as colour, is not wanting, but in thinking of courtship coloration it is probably safer not to be too analytic, crediting the female bird with too much in the way of particulate æsthetic discernment. It is probably the *total impression* of agility, beauty, vigour and other qualities which kindles or fans the fire of sexual excitement in the coy female.

The brilliant coloration of the males is in some measure latent in the females, as is shown in cases where an old female bird, or one with an abnormal ovary, begins to put on a masculine dress. The masculine characteristics are, as it were, seeds which will not normally develop except in male soil. They are parts of the inheritance, but they do not start developing except in appropriate soil and in response to appropriate stimulus. It has been shown experimentally that the stimulus, in some cases at least, is furnished by the ' hormones ' or internal secretions of the reproductive organs which are diffused by the blood throughout the body when the organism becomes adolescent or when the breeding season sets in. It is interesting to find

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many cases, e.g. pheasants, in which the brilliant coloration, which is in most cases 'nuptial', is a constant masculine character.

In Summary.—The point that we wish to emphasize in this brief survey of animal coloration is, that the pigment substances are primarily waste-products, reserve-products, or by-products of the animal's metabolism, and that in many cases the colours have no more significance for their possessors than the gorgeous autumnal tints of withering leaves have for the tree—that is to say, none! Similarly, the structural features that cause iridescence and the like are primarily the ripple-marks of growth. Likewise, in many cases, it seems probable that the colouring of special parts of the body is due to particulate conditions in different parts. Just as green vivianite may be deposited in the bones of a gar-pike, because of certain physiological conditions, so an island on the skin, the tip of an ear, the end of a tail may have a special colouring. In many cases, all theory apart, it is certain that the pigments have come to play an important rôle in the internal economy of the body, as in the case of hæmoglobin. From this basis, however, we must go on to the further step, that in the course of ages of variation and selection, certain arrangements of pigmentation and markings have been caught up, as it were, into the service of the animal's struggle for existence, and utilized, often with extraordinary subtlety and effectiveness, in concealment, in advertisement, as aids in recognition, and as auxiliaries in courtship. But to look everywhere for secondary utilitarian justification is quite gratuitous.

An interesting case of coloration is found in a sea-urchin, *Echinus angulosus*, common on South African coasts and

elsewhere. Dr. Stuart Thomson points out that many colours occur on different specimens—purple, red, green, grey, intermediate between purple and grey, intermediate between green and purple, pink, lilac, and so on. The coloration is variable. The investigator has tested various utilitarian interpretations, and finds them all untenable. The coloration is not protective, or aggressive, or for warning, or connected with sex. Its meaning is to be sought for in the internal physiological processes (probably respiratory or excretory) of the animals themselves. To this sound conclusion we have simply to add that it is *conceivable* that in the future the coloration might be caught up into the service of the sea-urchin's general life, and utilized, let us say, for protection.

Regeneration of Lost Parts

From ancient times something has been known of the regenerative capacity of living creatures. The pruned tree regrows its branches and a small cutting can re-grow the entire plant. The hair that is shaved off soon grows again—sometimes reproducing millions of cells every day, and the stag's antlers fall off and are re-grown every year. But it was not till the eighteenth century that scientific attention was focussed on the remarkable facts. It was then that Trembley discovered the freshwater polyp and called it Hydra, after the monster with which Her-

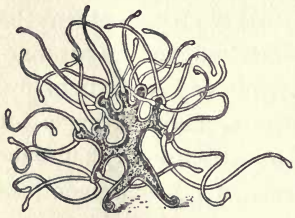

Fig. 89.—"Monster" form of *Hydra grisea*, with eight heads and two bases. (*After* Roesel von Rosenhof.)

cules contended, for he found to his delight that it could be multiplied by being cut in pieces. It was then that Spallanzani showed that the earthworm cut by the spade might re-grow a new tail or even a new head. Bonnet made numerous experiments on other worms and thought out an elaborate theory. Réaumur, with his wonted insight, advanced to an almost modern position when he pointed out the advantage of the regenerative capacity in animals which were in the natural conditions of their life exposed to frequent risk of breakage or wounds.

Instances of Regeneration.—During the last twenty years there has been a boom of experimental work bearing on regeneration—chiefly for the reason that the phenomena throw light on the physiology of development. Many remarkable facts have come to light, of which the following are typical:—half of the highly differentiated Infusorian Stentor can quickly regenerate the missing half and minute slices across the cell can re-grow the whole; from one Planarian worm six or more may be produced by cutting it into pieces; a starfish can re-grow a lost arm, and the lost arm can complete a new starfish; a crab can re-grow a lost limb; if the eye-bearing horn of a snail be cut off, it is regenerated over and over again, with the complex eye complete; if the front of the eye of a newt be cut off, a new lens is regenerated; a lizard can re-grow the tail which it has surrendered to its enemy; and a stork can re-grow a considerable portion of its lower jaw.

There is in certain types a remarkable exuberance of regenerative power. This is notably true of Amphibians. If the fore-limb of a newt or salamander is cut off across the humerus, it is normally re-grown, and this happens whether it is an adult or a larva. Nay more, in the same

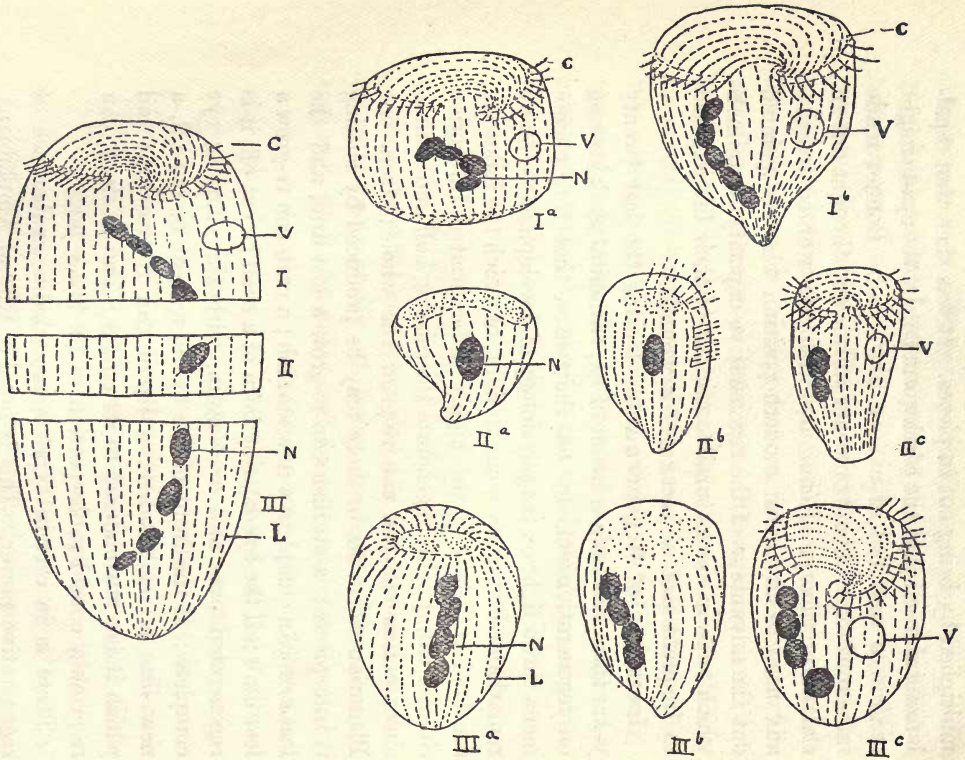

FIG. 90.—Regeneration of pieces of Stentor. (*After* Gruber.) C, cilia; V, vacuole; L, lines of cilia; N, necklace-like nucleus. Part I gave rise to I*a* and I*b*; Part II to II*a*, II*b* and II*c*; Part III to III*a*, III*b*, and III*c*.

animals, the removal of the entire limb and shoulder girdle of one side may still be followed by the re-growth of both —which is an extraordinary instance of regenerative capacity.

In *Linckia guildingii*, a starfish common on the reefs of Jamaica, the regenerative capacity is not less exuberant. Dr. Hubert Lyman Clark observed that arms or rays severed at some distance from the central disc give rise to new discs and rays, just as well as those which separate close to the disc. Rays are thrown off at irregular intervals for a long period, if not throughout life. In those rays growth continues, especially at the broken end, where new rays soon begin to appear, radiating out from a new mouth. It seems, indeed, that in this case the giving off of the rays and their subsequent regeneration of an entire starfish must be regarded as an important mode of asexual multiplication.

Analogous Phenomena.—It is always a step towards understanding to bring one kind of phenomenon into line with others. Thus it may be recalled that many of the results of experimental embryology show that part of an embryo has often the power of doing much more in the way of development than is normally required of it. If one of the first two cells into which the egg of a sea-urchin or a lancelet divides be separated off, it may form a complete embryo. A minute nucleated fragment of an egg may develop into an embryo, which lives for a short time at least.

Secondly, we may recall the familiar fact that in many animals there is an almost continual process of *tissue-regeneration* going on. Worn-out epidermic cells, glandular cells, blood-corpuscles, and so forth are all replaced by

what we may call a process of continuous growth. To meet the exigencies of normal life, the daily wear and tear, there is a continuation of local growth, which has certainly its bearing on the regeneration of accidentally lost parts. One of the noteworthy limitations of this tissue-regeneration concerns the nervous system in higher animals, for the number of nerve-cells does not appear to admit of any increase after birth.

Thirdly, it seems useful to remember that the process of asexual reproduction which many organisms exhibit is a utilization of the capacity of re-growing the whole from a part. Among Stinging Animals, Annelids, Polyzoa, and Tunicates there is often a normal giving off of a portion of the parent, which develops into a new individual. It may be a bud or an area of the body or a fragment—it is a part which is capable of re-growing the whole. The process is certainly to be brought into line with the regeneration of a lost part and with the regeneration of an entire individual from an artificially excised part.

It is instructive to consider cases where the power of asexual reproduction, which is normally a mere alternative, may become the main or exclusive means of continuing the species. This is well illustrated by the case of an Alpine Planarian, studied by Voigt. It is a relict of glacial conditions, a northern form, abounding in the hill streams around Bonn. Observation and experiment show that warmth hinders its sexual reproduction; out of 4,000 specimens not one was sexual; it is keeping its foothold in existence solely in virtue of its power of multiplying by division. In other words, a power which is, to begin with, only a subsidiary alternative, may in special circumstances become of essential importance. This should be borne

in mind in connection with the re-growth of lost parts.

Fourthly, it may be profitable to keep by themselves those cases where an artificially excised *small* fragment is able in favourable conditions to re-grow an entire organism. A fragment of a liverwort thallus will re-grow the whole plant, a piece of Begonia leaf will develop into a complete plant with root and stem and flower, a corner of potato-tuber with an "eye" has the same capacity—so familiar that it has ceased to excite our wonder. A piece of Sponge may be cut off and 'bedded out'; a Hydra may be cut into many parts each viable; one Planarian worm, half an inch long, may give rise to a dozen worms if cut into a dozen pieces.

Julian S. Huxley has confirmed H. V. Wilson's observations on the remarkable behaviour of cells strained off from chopped-up sponge. He worked with a common vase-like calcareous sponge, *Sycon raphanus*, and found that some of the cells moved like amœbæ and united into small confused clumps of irregular size—a process quite unlike anything that occurs in the ordinary life of sponges. Then followed processes of re-organization and re-development, in some respects like those of normal embryonic development. Two layers of cells were established, spicules were formed, a gastral cavity and an exhalent aperture appeared, and one of the 'regenerates' lived and grew as a functioning sponge for several weeks. This illustrates what we venture to call the indomitable virility of life.

We see, then, in approaching the problem of the regeneration of lost parts—say, lizard's tails, newt's legs, snails' horns, starfishes' arms—that it is useful to bear in mind some cognate phenomena:—(1) some of the facts of

experimental embryology which show that a cleavage-cell or blastomere may have no small amount of residual power beyond that which it normally expresses; (2) the normal process of tissue-regeneration which makes good the every-day wear and tear; (3) the frequency of asexual reproduction by buds or by fission; and (4) those cases where a minute fragment re-grows the whole.

Unequal Distribution of Regenerative Capacity.—One of the significant facts regarding the power of re-growing lost parts is its unequal distribution among the various types of animals. It is very common among worm-types, but almost absent in Nematodes—perhaps because a rupture of the body in these worms is rapidly fatal. It is common among Chætopods, but there is not much of it in leeches—partly because the slippery surface and tough body-wall make these animals but little liable to injury. It is very general among Arthropods, where legs are so liable to breakage, but there is not much of it among Molluscs, perhaps because most of these are shut up in shells. It is well seen in Amphibians, especially among tadpoles and newts, but it is not much in evidence among fishes. It is common among lizards, but there is little of it among snakes. A bird's toe or the end of a mammal's tail can hardly be regarded as more complex than a starfish's arm or the visceral organs inside a feather-star's calyx, but while regeneration is exceedingly characteristic of Echinoderms, it is at a minimum in Birds and Mammals.

When we follow the inequality of distribution into greater detail it becomes at once more striking and more luminous. It begins to reveal its significance. In many families of lizards it is the rule that a lost tail is regenerated, but in those lizards which strike with their tails, Werner has

shown that the regeneration is absent or very incomplete. Has the absence of it something to do with the fact that in those aggressive lizards that use their tail as a weapon, the loss of the tail is not likely to occur? Perhaps a clearer case is that of the Chameleon, which coils its prehensile monkeyish tail round the branch. There seems to be little or no regeneration, if the tail be cut off. Has the absence of it something to do with the fact that in the case of the quaint Chameleon, the loss of the tail is not likely to occur? Some of the limitations are less readily interpreted. Thus the weakly developed limbs of Siren and Proteus are not regenerated, but the well-developed limbs of the newt are. A salamander will re-grow an amputated limb if the bone be cut across and not disarticulated, but in a frog the wound heals without regenerating. The puzzle is why there should be such differences in the regenerative capacity of nearly related types. Another instructive case is that of the sea-urchin which cannot regenerate anything but its spines. Why is there this limitation in a member of the Echinoderm class in which the regenerative capacity is widespread and highly developed? Is it that the globular sea-urchin is not subject to the same risks as a starfish or a brittle-star?

Another general fact, which points the way to a theoretical interpretation, is that regeneration of internal parts is very rare among backboned animals, and rare even among backboneless animals except in cases like those of earthworms and starfishes, where the loss of part of the body necessarily injures the internal organs, such as the alimentary and nervous systems. If a rabbit's spleen be removed, it is not replaced; if a fragment be left, it does not grow larger. The removal of a kidney, a thyroid, a liver-lobe, and so on, is not known to be followed by regenerative

growth. Only in the case of reproductive organs does a remnant grow to replace what has been removed.

Lessona's Law.—These two sets of facts—the rarity of regeneration in the internal organs of higher animals, and the strangely unequal distribution of the capacity—point to a conclusion which seems to have occurred to several naturalists from Réaumur to Weismann, and was clearly summed up in 1868 by the Italian naturalist Lessona. According to 'Lessona's law', regeneration tends to be well marked in those animals, and in those parts of animals which are in the course of their natural life particularly liable to injury. To which, two saving clauses must be added, that the lost part be of some vital importance, and that the wound or injury be not in itself likely to be fatal. This theory, which is really Darwinian, has been re-stated by Weismann in the words: 'the power of regeneration possessed by an animal or by a part of an animal is regulated by adaptation to the frequency of loss, and to the extent of the damage caused by the loss'.

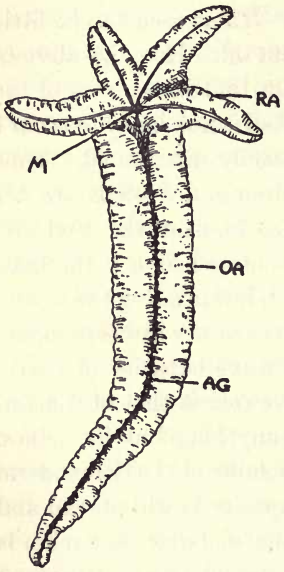

FIG. 91.—Comet form of starfish (Linckia). (*After* Richters.) An arm and a portion of disc regenerating the other four arms. M, the mouth; RA, a regenerating arm; OA, the original arm; AG, the ambulacral groove on the ventral surface of each arm.

It is evident, at once, that the lank and slender bodies

of worms, the long arms of starfishes and brittle-stars, the sprawling limbs of newts, the long tails of lizards, and so on, are naturally liable to injury, and that a regenerative capacity is one which natural selection would foster.

It is also evident that internal organs are much less likely to be cut out than external organs are to be cut off. It is also certain that visceral wounds are much more likely to be fatal in Vertebrates than in Invertebrates, so that a regenerative capacity in the former would be, so to speak, a quality wasted, whereas in the less sensitive Invertebrates, where it often occurs, it is very much in demand. If the retention and specialization of the regenerative capacity has been evolved as an adaptive character, it must obviously be restricted to cases where the injury is of a kind not likely to be fatal.

It will be observed that Lessona's law does not touch the question of the origin of the regenerative capacity, nor the question of how the capacity resides in the lizard's tail or in the snail's horn, nor the process of re-growing a complex structure from a stump. It is a theory of the *distribution* of the regenerative capacity—why is it here and not there, why is it strong in some animals and weak in others, why it is well marked in regard to some parts and not at all marked in regard to others. The question is whether it is a sufficient formula to cover the known facts in regard to the distribution of the regenerative capacity.

Testing the Theory.—One way of testing the theory is to inquire whether there are any or many well-authenticated cases of the regeneration of parts which would not be likely to be injured or lost in the natural conditions of the animal's life. A number of difficult cases have been

brought forward, and we may consider a few which may be called typical.

There is the well-known case of the stork's bill, which Weismann admitted to be difficult. The upper half was accidentally broken off, the lower jaw was amputated to the same length, in the course of time both were regenerated—a very remarkable achievement.

Now is there any evidence that such a serious injury might occur in ordinary life? If it is not a loss that is at all likely to occur, then it is not easy to understand why any organic provision should be made for its compensation. The difficulty was lessened by the report of Bordage, that in cock-fights similar injuries were frequent and were often followed by very remarkable regeneration. In one case the premaxillæ and part of the mandible were torn off—a large fraction of the entire beak—yet both bones and horny coverings were regenerated. Now cock-fighting, though elaborated by men of more or less evil device, is a natural phenomenon. Cocks are given to fighting furiously, injuries are frequent, and it is just the sort of ever-recurrent injury for the reparation of which provision might be made. When we discover, furthermore, that male storks also fight furiously, sometimes fatally, the difficulty of the stork's bill seems, as Weismann says, to become an exception proving the rule.

Another difficult case which Weismann discusses is that the eye of the newt (*Triton*) may be regenerated, as Bonnet and Blumenbach showed long ago, after serious injury. We now know that if the lens alone be carefully taken out, it will be replaced. These are very remarkable instances of regeneration, but the question immediately arises, What chance is there that in natural conditions a

newt should have its eye gouged out? To this Weismann answers that newts fight furiously, at any rate at the breeding season, and often injure one another; and that the larvæ of the large water-beetle (*Dytiscus marginalis*) often attack newts just behind the head. Moreover the water-snail Limnæa, though usually vegetarian, is sometimes found killing a newt, getting upon its back and filing the skin with its radula. It is probable that a more complete knowledge of the life of Amphibians would show that serious injury to the eye is not a rare casualty.

A very interesting case is given by Bordage. In locusts and related insects, the loss of one of the first two pairs of legs is followed by regeneration. On the other hand, the posterior or third pair of legs, which are of great importance in jumping, are not regenerated. Now why should this be, that the less important may be re-grown, while the more important are not? This seems quite inconsistent with Lessona's law. But Bordage points out that the loss of the posterior legs almost prevents moulting, leaves the locusts exposed to great danger, and, furthermore, prevents breeding. Perhaps therefore the case is covered by the corollary to Lessona's law—'provided the injury be not fatal'. Nor can one conceive how organic provision could be made for an injury which prevents breeding. The prevention of breeding is a full-stop to the evolution of an adaptive feature of any kind.

Some of the cases of regeneration are very remarkable. Kammerer has found that in the common house-fly (*Musca domestica*) and in the blow-fly (*Calliphora vomitoria*) amputation of a wing is not followed by any result, yet tearing off a wing from a newly pupated fly is sometimes

followed by re-growth. The new wing is at first homogeneous and transparent, it subsequently gets veins which seem to be after the normal pattern. The regeneration of a wing has also been observed in the meal-beetle (*Tenebrio*). In Nature an insect bereft of wing would be likely to die, nor is the accident very likely to happen often unless in Lepidoptera, where the removal of a wing is followed by no result. It seems difficult therefore to suppose that the regenerative capacity is always adaptive.

An interesting peculiarity in connection with regeneration in the starfish may also be used as a test case. Miss Helen D. King points out that in *Asterias vulgaris* it is quite usual for an isolated arm to regenerate the whole if it has a fraction of the central disc left. ' Comet-forms ' are not infrequent, which consist of a fully-developed arm, a partially formed disc, and four beginnings of the arms which are missing. One of these forms is figured (Fig. 91), and every shore-naturalist is familiar with every possible transition between the single arm and the intact starfish. All this is well known, but what Miss King's experiments brought out was the fact that while the ventral part of an arm may regenerate the dorsal surface, the converse does not occur. It may be said, of course, that this is simply because of the complexity of the ventral surface, with its tube-feet, water-vessel, nerve-strand, and so on. But it is just possible that the reason may be different, and connected with the obvious fact that the dorsal surface is, in natural conditions, much more open to attack and injury than the ventral surface which adheres to the rock. Again, perhaps, the exception proves the rule.

Another apparent difficulty which turns out to be a corroboration is expounded by Bordage. The lower or

tarsal joints of the legs of locusts and the like are readily dislocated, and in the two front pairs they are readily regenerated. It requires great force to break the leg near the top between joints 1 and 2 (coxa and trochanter), or still more between parts 2 and 3 (trochanter and femur). The injury is often fatal. But the remarkable point is that if the insect survives and is young, regeneration may be effected, especially if the dislocation is between joints 2 and 3, *where it is most difficult*. This seems to be an extremely difficult case, for after making all allowances for the various and violent ways in which locusts may be pulled about by one another, or by birds and other enemies, it is difficult to see how in natural conditions sufficient force would be exerted to break the leg, and still more difficult to understand why regeneration should most frequently follow when the breakage occurs at the most difficult place.

Yet the difficulty is not insurmountable, for observation of the frequent moultings shows that when the locust is struggling out of its old clothes or cuticle, breakage at the joints is very apt to occur, *particularly at the trochanter-femur articulation*, which afterwards becomes so strong. The difficulty disappears and becomes an argument in favour of the view that the distribution of the regenerative capacity is *adaptive*.

Similarly, Bordage has shown in regard to Walking-Stick Insects, or Phasmids, where the assaults of birds and lizards seemed to afford insufficient reason for the prevalent habit of breaking off a leg at a particular line and re-growing it thence, that the breakages during emergence from the egg or from the cast moults have probably furnished sufficient reason for the evolution of the restorative

provision. On a point like this it is interesting to get precise facts, and Bordage notes that out of a hundred Phasmids, nine died during moulting, twenty-two tore themselves free with the loss of one or more legs, and only sixty-two survived without any loss. In short, breakage during moulting is a frequently recurrent casualty, provision for which would certainly be favoured by natural selection.[1]

Another difficulty is presented by the regeneration of the abdominal limbs of hermit-crabs, which are normally protected by the Gastropod shell which the Crustacean borrows. There are five of these—the first very rudimentary in the males, but used for carrying the eggs in the females; the fourth and fifth used to fix the hermit-crab to the central pillar of the borrowed shell. It is evident that there is little likelihood of these limbs being nipped off—extremely little in the case of the two hindmost pairs. But Professor T. H. Morgan has shown that *all* the limbs of hermit-crabs are capable of regeneration, though they do not all grow again equally often, the anterior abdominal appendages being less frequently renewed than the more exposed thoracic limbs, for even these are not always restored after loss. He therefore argues that there is here no relation between frequency of loss and regenerative capacity—a thesis quite counter to the idea of Lessona's law. Weismann's general answer is that the regenerative capacity shown by the hermit-crab's abdominal limbs may be a persistent inheritance from ancestral forms which must have had exposed tails. Moreover, one would like to inquire particularly into the life of hermit-crabs to find out whether there are not now—in the combats, in the flitting from one house to another, and particularly in the

moultings—some very good present reasons for the retention of the regenerative capacity in the abdominal appendages.

Imperfect Regenerations.—Another objection to the theory which interprets the distribution or occurrence of the regenerative capacity as adaptive is found in those strange and highly interesting cases where the re-growth takes place, but not according to pattern. As Spallanzani showed in 1768 and T. H. Morgan in 1899, a decapitated earthworm may grow a second tail (as shown by the disposition of the excretory tubules or nephridia) instead of replacing its lost head. But this only serves to show that the regenerative process is liable to go wrong at times just as the embryonic development does. The fact that a headless creature is sometimes born does not affect the general conclusion that development is a regulated and harmonious process.

Werner points out that when a lizard re-grows its tail, it does not always adhere to the pattern. When the scales are comparatively simple, the regeneration is almost perfect, but when the scales are complex and there is much ornamentation, the regenerated tail is simpler than the one that was lost; *it tends to be an ancestor's type of tail.* Hence the wit has suggested that to find out a lizard's pedigree, you have only to pull off its tail. Perhaps a truer way of stating the case, however, is that the regenerated tail is nearer the embryonic type, which is not surprising if regeneration be due to a local persistence and re-awakening of embryonic growing powers.

There seems to be a widespread tendency towards the reproduction of a simpler or ancestral form, or, in some cases, of a simpler and more embryonic form. Thus in cockroaches and walking-stick insects (Phasmids), which have

normally five tarsal joints at the end of the leg, the regenerated limb has only four tarsal joints, which is believed to be the ancestral number. Weismann cites the observation of Fritz Müller, that in a Brazilian shrimp, *Atyoida potimorim*, the long clawed forceps are replaced in regeneration by the older short-fingered type of forceps, seen in the allied genus *Caridina*. In both these cases it might be said that the regeneration was economical and that not more than a workable substitute for the lost part was re-grown. But this cannot be the explanation, for we know that regeneration will take place perfectly in half-starved animals. Furthermore, there are cases where the regenerated part, though more ancestral, is not more economical of material. Thus Barfurth calls attention to the very suggestive fact that the four-fingered hand of the Axolotl is replaced after amputation by a more typical five-fingered hand.

Weismann has suggested a speculative theory of these cases. He supposes that there are regeneration-germs which come to reside in areas particularly liable to injury (like the cambium-cells in various parts of plants), and he further supposes that these have, in their developmental power, lagged a little behind the level of the part to which they correspond. They are able to replace it, but not quite up to the contemporary grade of evolution. It must be remembered that the regeneration tends to be rapid compared with the original development, and that the conditions are different. Perhaps some stimulus is awanting to incite the regeneration to go a step further.

It must be admitted that in many cases the substitute that replaces the lost part is not quite correct, not quite up to the mark. In place of a lost leg an insect may grow

an antenna; in place of an antenna a leg. Instead of a lost abdominal limb the edible crab may grow a walking leg, which is very much out of place, and instead of a lost stalked-eye the lobster may grow an antenna. Many cases, indeed, are known where a Crustacean does not get an eye for an eye, but something simpler. Most of these cases of imperfect regeneration concern animals whose limbs normally pass from one form to another with successive moultings, and, as Przibram suggests, it is worth asking whether the antenna instead of an eye was really the *final* result of the regenerative process. The animals should be kept alive when possible, and the observation continued until after the next moult. In his experiments on the common water-flea, *Daphnia*, and on the Isopod, *Asellus*, he found that the regenerated limb was not at first perfect, but became normal after repeated moultings.

Regeneration and Embryonic Development.—In many cases the process by which regeneration is effected is very like the normal process of typical development, which is perhaps what one should expect on *à priori* grounds. The ectoderm or outer layer of the cut surface furnishes the ectoderm of the re-growth, and the mesoderm the mesoderm. But in some cases the regenerative growth is very different from that which occurs in embryonic development, and we have to face the puzzle that the same result may be reached by two different paths.

When the anterior end of a Naiad—a freshwater worm—is cut off, an ectodermic cap is formed, according to Hepke, over the wound; in the concave interior of this cap there gradually appear all the organs to be replaced; muscles, which are normally mesodermic, are formed by cells migrating from the ectoderm, and a piece of food-canal, which

ought by rights to be endodermic, is formed by the ectoderm. There are not a few cases of this sort, and it is plain that regenerative growth does not necessarily follow the path of embryonic development. The same sort of difficulty arises in connection with the buds of Tunicates and Polyzoa which reach the same general result as a fertilized ovum, but by quite different paths. Perhaps we have here a hint that we may create unnecessary difficulties by making too much of the distinctiveness of the germinal layers.

Another much-discussed case must be cited. Calucci, Wolff, and Müller have made the experiment of extracting the lens of *Triton*, with the result that it was normally regenerated. From what, however? Not from remnants of the lens, for there were none, but from the iris, with which the lens (a product of the ectoderm in front of the optic cup) has no genetic connection. That an iris should be able to regenerate an iris would be consonant with the general facts of regeneration, but it seems to be able to re-make a lens, in whose original making it plays no part. It may be pointed out that the posterior epithelium of the iris is ectodermic like the lens, and furthermore that the newt is an animal with great regenerative power in many parts, and may be contrasted with an animal like the rabbit, where regeneration of the lens does not occur unless some portion of the lens be left. Perhaps, however, the case of the newt's lens points to the conclusion that the residual germinal capacity, localized here and there in animals, is more general and less specific than is sometimes supposed, and that what occurs in any particular instance is under some sort of *regulation*, so that what is most needed tends to be done.

The Wonder of Regeneration.—It is striking to see how from within its cuticular sheath there suddenly bursts forth a beautifully formed lobster-limb, replacing one that has been lost. It is liberated at a moult, and stretches itself out like a Jack-in-the-Box. The occurrence seems almost magical, but we must not be misled. The abruptness of the phenomenon is wholly superficial, there has been a long period of gradual differentiation within the husk of the limb-bud. There are not many Jack-in-the-Box phenomena in organic Nature. Her magic is quiet.

Therefore one of the things to be borne in mind is that in regenerative growth, just as in embryonic development, one phase naturally and gradually leads on to the next. The stump of a snail's horn will re-grow the whole horn, with the eye at the tip included, and will re-grow it not once but many times. But there is nothing sudden, the horn is fashioned with a gradually increasing perfection, reminding one of the growth of, let us say, a coronet in the craftsman's hands. The words gradual differentiation and integration do not solve any mystery, but they may save us from a false impression.

We are probably unable in the present state of science to utilize to proper advantage the analogies between crystallization and growth; but it is interesting to remember that a minute fragment of alum fashioned artificially into a sphere, or a cylinder, or a lens, will, when dropped into a solution of alum, develop into a perfect octahedron, through what Rauber has called an imperfect embryonic stage. A sphere of saltpetre will similarly regenerate a rhombic prism, and any mutilation of a crystal will be followed by a restoration of the normal form. Now the gap between the little spherule of alum and the perfect

octahedron is remotely comparable to the gap between the regenerative hood that forms at the anterior end of a decapitated freshwater worm and the perfectly re-grown head. In both cases there is a gradual series of differentiations and integrations connecting the beginning and the end.

Again, without detracting from the genuine wonder of the facts of regeneration, we may reasonably seek to bring them into line with analogous phenomena, and we have already referred to asexual multiplication, tissue replacement, and the like. Let us recall also what occurs inside the pupa case of a fly, where the larval body is literally disintegrated, and certain minute groups of cells (the imaginal discs) act among the debris as the centres of a reconstruction on an entirely new plan.

When we think of the earthworm growing a new head, or the lizard a new tail, or the newt a new lens—all, as it were, at command—we must try to allow for the influence of environing stimuli. The residual germinal power in the animal counts for much, but this operates under the influence of a particular environment, which also counts for much, though not for so much. Perhaps this point may be best understood by reference to what is technically called heteromorphosis, which means that in certain conditions the re-growth departs from its ordinary mode of procedure.

If an inch or two be cut from the cylindrical stalk of the common zoophyte Tubularia, and one end be stuck in the sand, a head may be re-grown at the free end whether that was originally turned towards the head or towards the base. But if both ends be left free, the piece regenerates a head at each end. Evidently the environmental influences count for something here. There are

many similar cases which suggest that the result is, as it were, a compromise between the inherent growth-tendencies of the organism and the environmental stimuli operative in each case.

Theoretical Considerations.—In what way is it possible for us to imagine the regenerative capacity of organisms? A crocodile loses a tooth, but beneath its hollow base there lay another which now fills the gap. Not far off there is a rudiment of another, and so on. The adder casts a fang, but there is another ready to slip into its place, and to re-establish in a very interesting way the connection with the poison duct. Not far off there is a rudiment of another fang, and so on. But when a crab loses a claw there is no under-study lying ready at the area of rupture. There is no rudiment of a visible nature, and yet the regeneration is duly effected. How can we conceive of this?

In certain cases, as in plants, there is visible evidence of persisting embryonic tissue—the cambium—which has retained the formative capacity of the original fertilized egg-cell. In many of the lower animals, such as polyps, division of labour has not gone very far, and there are visible 'interstitial cells' which have remained undifferentiated and might be compared to the cambium cells of plants. But in most of the cases which we have discussed in this chapter regeneration takes place from amid a stump of differentiated cells. In some instances there is an apparent undoing of the differentiation, a return to a simpler type, and a multiplication at a embryonic level. Sometimes considerable assistance appears to be afforded by migrant amœboid cells of the body—the phagocytes—which appear on the scene of the accident and are very

active in various ways. But they are by no means indispensable. On the whole, in the present state of our knowledge, it seems that the best working hypothesis is Weismann's. He supposes that the germ-plasm includes special 'regeneration-determinants' which are distributed appropriately through the body and lie quietly like garrisons in strategic places, awaiting a possible awakening stimulus.

Perhaps, however, it is at present wiser to leave our conception of the arrangements for regeneration somewhat vague, and to concentrate attention on the case for Lessona's law—that regenerative capacity tends to occur in those animals and in those parts of animals which are in the natural conditions of their life particularly liable to injury, always provided that the part lost be of real importance, and that the injury be not fatal. All of which comes to this, that the distribution of the regenerative capacity is *adaptive*, and can be accounted for on the theory of Natural Selection.

The Crowning Wonder of Evolution.

We have become so familiar with the general idea of organic evolution that we have ceased to wonder enough. It should be a thought to thrill us, that we and the multitudinous, varied, intricate, and always beautiful world of life around us have grown by infinitely slow gradations from an apparently simple beginning. Through unreckonable ages Life has been slowly creeping upwards, possessing and conquering the earth ever more thoroughly, unfolding new and unsuspected potentialities æon after æon, and affording us in fact no small part of the material that has gone to build up our conception of Progress.

It is a grand piece of history beyond doubt—the prehistoric history of the organic world. If our conception is right at all, there once was a time when the living creatures of the Earth were very minute corpuscles of living matter —very simple but individuated, able to feed, grow, and multiply, able to enregister their experiences. We must try to think of them as simpler than any of the Protists that are visible to-day. Perhaps the ultra-microscopic Chlamydozoa may be nearest to them.

Great Steps in Evolution.—Looking backwards we see a great succession of achievements. Within the realm of the unicellulars we find every grade of structural differentiation—some relatively simple, some extraordinarily complex like many of the Radiolarians. We can still trace the gradual specialization of functions, the establishment of the great types of cell life, the beginnings of reproduction and of death. One of the earliest steps was the dichotomy which separated plants and animals—the most momentous cleavage in evolution.

A simple instance may serve to bring out the point that functions have become more specialized as evolution proceeded. W. Staniewiez has called attention to the interesting fact that Protozoa have never learned to digest fat. All multicellular animals have this power, but the Protozoa have not. Experiments with Paramœcium, Stentor, and some other common Infusorians show that fat may be ingested, but it is not digested. It is not a natural part of a Protozoon's food, and the fat that is occasionally found in natural conditions within the Protozoon cell seems to be due to the transformation of proteids or carbohydrates. If the facts are correct, the power of digesting fat was added on to the digestive function when the transi-

tion was made from unicellular to multicellular animals.

When certain simple organisms, unable fully to complete that division into two or more separate units which normally occurs at the limit of growth, began to form multicellular 'bodies'—one of the greatest steps in evolution was taken. It was perhaps with the acquisition of a body that natural death began. It was certainly with the acquisition of a body that there began the very advantageous division of labour between body-cells and germ-cells. Among the Protozoa there are often dimorphic units which combine in fertilization or conjugation, and they are the analogues of the ova and spermatozoa of higher animals; but it was only after the establishment of the multicellular body that the sexes, in the strict sense, were differentiated as sperm-producers and ovum-producers—males and females respectively.

Another step with far-reaching consequences was the replacement of the radial symmetry of polyp and jellyfish by bilateral symmetry. It was some 'worm' types which began the useful habit of moving with one end of the body always in front, and with this was associated the acquisition of head-brains,—the beginning of the process which has led to our being able to tell our right hand from our left.

We think of what was implied in the discovery of an oxygen-capturing respiratory pigment like hæmoglobin, or of an armouring substance like chitin which is characteristic of the highly successful Arthropod alliance of Crustaceans, Insects, Spiders and the like. The early differentiations of striped muscle and specialized sense-organs were other great events, and much was gained by such a simple step as having a food-canal open posteriorly

and not blind, as it was to begin with. Another great invention was the blood itself, a fluid tissue, transporting digested food, carrying oxygen and carbon dioxide, draining away the nitrogenous waste, and distributing the regulative hormones produced by organs of internal secretion.

Looking backwards we see that there has been a wonderful twofold progress—in differentiation and in integration. On the one hand, bodies have become more complicated; on the other hand, more unified and controlled. In particular, we see that life has become richer and freer as the nervous system became more complex and more unified. A fresh start was doubtless made when backboned animals emerged, it is difficult to say whence or how, for with them the possibilities of a distinctly higher life began, with more intelligence and less instinct, with more mastery of the medium. We think of birds, of mammals, and of man; of the detailed colonization of the earth and the exploitation of its resources; and of the consummate adaptations seen at every turn.

One of the big impressions is the gradual emergence of nobler forms of life. Millions of years passed before any backboned animals appeared. The earliest fossil fishes are obtained from Silurian strata; the first Amphibians are much later—in the Carboniferous; the Reptiles probably began in the Permian; the oldest known bird, Archæopteryx, is Jurassic. Some races reach their climax and begin to wane, but if we take the Vertebrate series, we may say in general terms that the rock-record reveals a slowly increasing perfection.

To refer to a concrete detail, it is strange to think of the fact that it was not till millions after millions of years

had passed that living creatures found a voice. Apart from the instrumental noises of some insects, it was not until the advent of Amphibians in the Carboniferous age that the silence of nature was broken by any voice of life. It is useful to fix attention on one race and to note what they achieved, and no one surely can look at the fossil remains of the Carboniferous Amphibians without a thrill. They are the remains of pioneers—the first backboned animals to begin the possession of the dry land, the first to have finger and toes and thus the power of feeling things in three dimensions, the first to have a voice and a mobile tongue, and the first to have true lungs. How many acquisitions these early Amphibians made!

Mr. W. D. Matthew, of the American Museum of Natural History, has written appreciatively concerning *Eryops*, a primitive Amphibian which lived about the close of the Carboniferous Period—'five times as old as *Eohippus* (an early ancestor of the modern horse), a hundred times as old as the mammoth or mastodon or the earliest known remains of man'. It was 'a sort of gigantic tadpole or mud-puppy, with wide flat head, no neck, a thick heavy body, short legs and paddle-like feet and a heavy flattened tail'. Heavy and clumsy, small-brained and slow, but it was near the top of the genealogical tree in its day, and it was rich in promise! 'The giant dragon-fly that darted over the head of the slow-crawling *Eryops* might seem, except in size, a far superior type of being, a far more promising candidate for the position of ancestor to the intelligent life which was to appear in the dim future'. But the facts were far otherwise. The giant dragon-fly had already reached the limit of great organizational change, while 'the amphibian was but beginning the

adaptation of the vertebrate structure to a terrestrial life'. It had not circumscribed its possibilities, and perhaps there is something in Professor Shaler's suggestion, that the possession of an internal instead of an external skeleton was a factor in giving free play to the evolutionary potency which lay concealed in these unpromising amphibians of the Carboniferous forest-swamps.

The Fitness of the Environment.—A favourite idea of olden times was expressed in the phrase *the harmony of nature*, the theory being that the physical conditions, for instance, were suitable for life. The universe was regarded as distinctly friendly. This idea has been rehabilitated in Professor Lawrence J. Henderson's recent essay on *The Fitness of the Environment* (1913), to which we wish briefly to refer. When a crust forms on a heavenly body, like our earth, the normal envelope is an atmosphere containing water and carbonic acid gas, which are necessarily and automatically formed in vast amounts by the cosmic process. They are very fit things in themselves, and fitted to play an important rôle in inorganic evolution, but the point is that they also exhibit extraordinarily great and detailed fitness in relation to the upbuilding and sustenance of living creatures. Their exceptional properties have contributed to the success of life. There are no other compounds which share more than a small part of the qualities of fitness which water and carbonic acid possess; and no other elements which share those of carbon, hydrogen and oxygen. Living means trafficking with the environment; to do this effectively organisms must be complex and yet coherent, plastic and yet durable; and they were able to gain these qualities because of the fundamental properties of the primary constituents of the inanimate environ-

ment. In the same manner, the oceans which were formed automatically in the course of the cosmic process have in certain respects a maximal fitness in relation to life. Even our own blood, which is such an effective internal medium, seems to owe some of its virtue to Father Neptune.

'The fitness of the environment results from characteristics which constitute a series of maxima—unique, or nearly unique properties of water, carbonic acid, the compounds of carbon, hydrogen, and oxygen and the ocean—so numerous, so varied, so nearly complete among all things which are concerned in the problem, that together they form certainly the greatest possible fitness. No other environment consisting of primary constituents made up of other known elements or lacking water and carbonic acid, could possess a like number of fit characteristics or such highly fit characteristics, or in any manner such great fitness to promote complexity, durability and active metabolism in the organic mechanism which we call life'. . . . 'In fundamental characteristics the actual environment is the fittest possible abode of life'.

It seems to come to this that ours is the best of worlds. It is certain that the earth could not have become the home of the living creatures that we know unless it had gone through stages of chemical and physical preparation. It is certain that the physical basis of life as we know it could not have been formed unless there had been in matter a tendency to complexify—to form atoms, molecules, enormous molecules, and those unstable aggregates of molecules which we know in colloids. It is also certain that the compounds of carbon, with their large molecules, and power of colloidal union, are such as to favour the increase of structural complexity, e.g., as we see it in the

physical basis of life. And so on, for, as Prof. Henderson has well shown, the evidence is cumulative that living creatures, as material systems, are in no wise foreign to the earth but are in the deepest sense congruent with it. This is a very important and sound conclusion.

Yet we cannot follow Prof. Henderson to his conclusion that 'in fundamental characteristics the actual environment is the fittest possible abode of life'. It may be so, but the assertion outstrips the evidence. That we cannot suggest another plan of evolution, another kind of make-up for the physical basis of life, does not by any means prove that there could be no other, no better. Who can tell that there may not elsewhere be other and fairer faunas and floras which biologists of another and of wiser sort rejoice to study?

While it is a notable and valuable service to have shown what we may call the solidarity of organisms and their environment, is there not a risk of arguing in a circle, and making a problem where none exists? We must remember the old lady's fallacy regarding rivers and towns. If we grant, as Meldola says, that the elements have not been launched haphazard into existence as independent entities; if we admit a tendency in matter to complexify when it gets a chance (a tendency no more explicable than gravitation); if we suppose, as the author does, that 'the whole evolutionary process, both cosmic and organic, is one', why should we be surprised at the 'two complementary fitnesses'? The characteristic properties of water and carbonic acid, of carbon compounds and colloid states, are peculiarly fitted for the life of organisms, because organisms as mechanisms (and our author does not consider them otherwise) are such as could arise and survive and evolve

under the given environmental conditions. The earth is friendly to living creatures because in their physical nature they are bone of her bone, and flesh of her flesh—her very children.

But it is an important piece of work to have shown that organisms cannot be thought of as episodically or contingently fitted to their environment, that the 'natural characteristics of the environment promote and favour complexity, regulation, and metabolism, the three fundamental characteristics of life'. The characteristics that make them fit have contributed to the fitness of organisms. It is no small service to have so clearly and circumstantially suggested that Nature is Nature for a certain purpose.

The Method of Evolution.—So far as we know as yet, the method of organic evolution has been the method of trial and error: ceaseless experimenting on the part of the germ-cells, and the submission of these tentative new departures to that criticism by the environment, which we call Natural Selection. The experiments are called 'variations', and there is a growing body of evidence to show that we must distinguish the minor fluctuations from the major mutations. (It does not seem likely that 'modifications', or the direct results of peculiarities of nurture in the wide sense, are of any direct importance in evolution, since we have no secure evidence that they are ever transmitted, as such or in any representative degree.) The facts in regard to 'mutations', which we owe to De Vries, Bateson, and others, point to the occurrence of sudden and discontinuous variation; 'the existence, that is to say, of new forms having from their first beginning more or less of the kind of *perfection* that we associate with normality'. The general idea is that novel characters

may suddenly appear, as it were, full-fledged, with considerable perfection from the moment of their emergence, and without intergrades linking them to the parents. Furthermore, the novel character of the mutant, if we may use the word, is independently heritable and does not blend; it can be grafted intactly on to another stock, or it can be dropped out as such. Again, mutations are on the whole qualitative, as contrasted with the quantitative fluctuations. It comes to this, then, that the elusive Proteus, which is the essence of every living creature, is ever changeful, sometimes leaping ('mutations', we call the movements), sometimes taking short tentative steps ('fluctuations', we call them).

As to the origin of fluctuations and mutations we must still confess with Darwin that our ignorance is profound. Is it a fundamental characteristic of organisms, that they tend to vary and often to vary creatively? So much must be allowed for the effect that fluctuations in the nutritive stream of the body may have in evoking responsive changes in the complex germ-cells. So much must be allowed for the effect that searching environmental changes may have in acting as liberating stimuli to the germ-cells—pulling the trigger of their potentiality. So much must be allowed for the opportunities afforded in maturation and fertilization for shuffling the chromosome cards, producing new combinations or dropping out an item altogether.

Perhaps we can go a step further, recalling, for instance, what Herbert Spencer emphasized, and what the progress of chemistry since his day has made even more vivid, the tendency in matter to complexify—corpuscles forming atoms, atoms molecules, molecules larger molecules, and so on. Perhaps the living unit, which we know as the

germ-cell, utilises this complexifying tendency in a progressive differentiation of its own. Just as the same chemical substance may crystallize in more than one way, so, but more subtly, the germ-cell may experiment with its architecture. The germ-cell is no ordinary cell, it is a gamete, a condensed individuality; and just as an intact organism, from Amoeba to Elephant, tries experiments, so it may be that the implicit organism of the germ-cell tries experiments—which we call variations. Such at least is our view of a great mystery.

It seems, then, if we are reading the story of Evolution aright, that a genius may be born like Minerva from the brain of Jove. There is brusquely a new pattern, 'something quite original', a mutation. It used to be a dogma: *Natura non facit saltus*, but evidences of *Natura saltatrix* are rapidly accumulating. They spoke of life 'slowly creeping upwards'—but the Proteus leaps as well as creeps. There is doubtless some progress by thrift, by adding one to one to make a thousand, but it is beginning to be clear that Nature gambles. The great steps in evolution were probably made by *grands coups*, not by savings. Many of them express new ideas, and it is difficult to see how a new principle in organization could originate gradually.

While modern biology lays more emphasis on what may be called the *organismal factor* in evolution—what is attainable by the creative experiments of the organism, especially in the germinal part of its life—this is in no way inconsistent with the Darwinian theory of Natural Selection, or Nature's sifting. The raw materials are the inborn variations; the internal condition of progress is their heritability and their consistency with the rest of the organism; the external condition is the struggle for existence

in its manifold forms; the process is discriminate elimination; and the result is the survival of the variants fittest to the given conditions.

Referring, for discussion, to our '*Darwinism and Human Life*,' we wish to emphasize what seems to us of the greatest importance, that Nature's sifting is extraordinarily manifold and subtle, as Darwin always insisted. The struggle for existence is much wider than is suggested by the words taken literally. It expresses the sum total of the reactions which living creatures make to their limitations and difficulties. We see the struggle for existence wherever living creatures press up against limiting conditions; wherever living creatures, with their powers of growing and multiplying, thrusting and parrying, changing and being changed, competing and combining, working for self and working for others, do in any way say, 'We will live'.

In the same way the Natural Selection which Darwin spoke of metaphorically as 'daily and hourly scrutinizing throughout the world the slightest variations', is only thought of truly when it is thought of subtly. For it comprises all the forms of *discriminate criticism* which meet the experiments or variations of organisms, now working with dramatic swiftness in killing off unfit variants even before they are born, again working with imperceptible slowness giving to some a slightly longer life or a slightly larger family, now singling the full-grown, and again the young, and again the germ-cells themselves. As Goethe said, 'Nature's children are numberless. To none is she altogether miserly; but she has her favourites, on whom she squanders much, and for whom she makes great sacrifices. Over greatness she spreads her shield'.

Summary.—Our view is that the organism is the

product—the creation-result—of the germ-plasm with its great uniformity and yet ever-newness, and the environment with its great uniformity and yet ever-newness. The germ-plasm is variable, that is to say it makes experiments, some futile, like every artist's, some successful. Those that are successful are so because their urgent fingers fit into the environmental glove. But this metaphor is on one side too static. For the germinal experiments that succeed are those to which the environment offers, as it were, encouraging opportunity for expression.

Tactics of Nature.—What we have said in regard to the method of organic evolution refers only to the general formula, and we cannot here do more than illustrate the answers to the interesting further question that arises as to the detailed tactics in particular cases. The production of such geniuses as ants and bees, wasps and spiders, rooks and cranes, elephants and horses, remains more or less of a mystery. Though in some cases, such as elephants and horses, we have considerable information as to the historical stages of evolution, we have little light in regard to the organic urge which may have accounted for the successive uplifts. As has been said, we understand the survival but not the arrival of mutations. It is different, however, when we turn to Nature's method of making extraordinarily new things out of very old things. For this is what has happened in a great number of cases where something apparently novel has emerged. The old is, as it were, recrystallized. The mineral becomes a jewel. Let us give a few illustrations.

The spinnerets of a spider are very novel contrivances, but they apparently represent transformed limbs. The butterfly's spiral proboscis is a coiled jaw and the bee's

sting an elaborated ovipositor. The serpent's fangs are folded or channelled teeth, and the reservoirs of venom are but specialized salivary glands. The milk-glands of mammals seem to have arisen from clusters of sebaceous skin-glands, common to both sexes. Every schoolboy knows that the elephant's trunk—an extraordinary novelty in

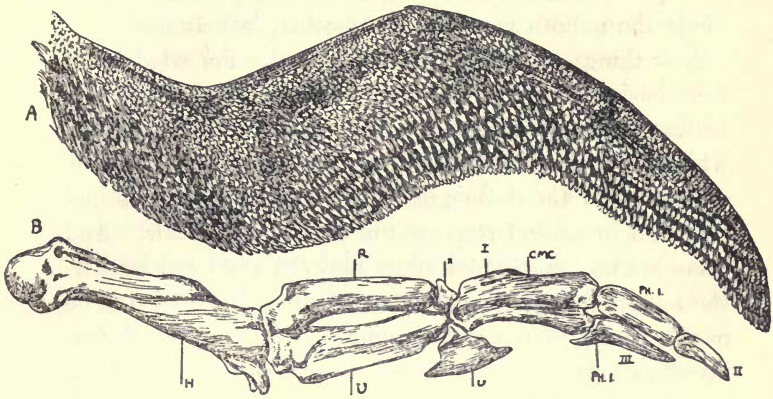

FIG. 92.—Wing of Adélie Penguin, Pygoscelis adeliæ, illustrating the fact that a very novel structure, a flipper, may arise by a not very great transformation of an older structure—a wing. (*After* Pycraft.) A, the entire wing covered with small flat feathers; B, the bones of the wing; H, humerus; R, radius; U, ulna; R, radiale, one of the two free wrist bones; U, ulnare, the other free wrist bone; CMC, carpometacarpus, part of wrist and palm fused; I, thumb bone fused; II, second digit with two joints or phalanges; III, third digit with one joint (PH. I.).

its day—is just the creature's nose, and every student of comparative anatomy can tell us how the hammer and anvil that form part of the delicate apparatus for conveying vibrations to the inner ear were once part and parcel of the rougher and more commonplace mechanism of the jaws. There is no doubt that to make an apparently very new thing out of a really very old thing is part of Nature's magic

The idea which we have illustrated was clearly expressed by Dr. Anton Dohrn, the founder of the famous Zoological Station at Naples. He called it 'the principle of function-change', and showed, for instance, that the unimportant bladder which grows out from the hind end of the gut in frogs, becomes an all-important birth-robe, the allantois in reptiles and birds, and part of the placenta, which binds the unborn young to the mother, in mammals.

New things out of old, that is the law. For what could have been newer in its day than a feather, and what is a feather but a glorified scale? In regard to this homology, which Aristotle discerned so long ago, there is still a little difficulty, for the development of a feather is very distinctive and in several respects unlike that of a scale. And there are no transitional types between scale and feather, the minute flat structures on a penguin's flippers being no nearer scales than are the plumes of an eagle. Recent investigations, such as Frieda Bornstein's study of the foot of the capercaillie, where feathers and scales occur in close association, point to the conclusion that a feather corresponds not to a whole scale, but to part of a scale, another part being suppressed. But none the less the feather illustrates the evolution of the new from the old.

As another illustration of tactics we would briefly refer to the idea of temporal variations which has been expounded by Professor Patrick Geddes. In the chapter on 'The Cycle of Life' we have spoken of the changes which may come about by lengthening out one chapter of the life-history and compressing another, by altering, as it were, 'the time' of the tune at different periods. It seems that we can interpret not a few evolutionary changes in the light of this idea. For some types are all youth, and others

are born old; some telescope adolescence and others draw it out for many years. It is plausible, and, as we say, suggestive, to regard certain types as arrested juveniles and others as precociously senile, just as we have plants which remain as great buds and others which are all flower.

The idea is the more valuable because we know of an agency in higher animals by which the rate of development of particular parts can be altered. It has been shown that internal secretions have a regulating action on the growth of parts of the body. Some act as accelerants, others as inhibitors. It is said that 'infundibular extract (from the pituitary body) has been employed with success in recent years in order to add in a short time a few desirable inches to a young man's height. So that it seems, after all, as if one may, by taking sufficient thought, add a cubit to one's stature. In other cases, it is the absence of a specific secretion that causes some particular part to grow abnormally large, as if some brake were removed. Prof. Arthur Dendy has suggested that this internal regulation of growth may account for cases where animals or parts of animals seem to have acquired some sort of momentum, growing far beyond the limit of utility. A disappearance of certain glands, or some change in the secretion of certain glands, may remove the normal brake, with the result that a part which was wont to be controlled as to its growth by a specific secretion or 'hormone', may grow far beyond its optimum, and may indeed become fatal to its possessor.

Another theory, deserving of more than brief illustration, is suggested by Virchow's idea of an optimism of pathology. Certain organic diseases are due to constitutional variations which tend to the wrong side of viability, but those germi-

nal variations that miss are not far removed from those that hit, and what misses in one type may hit the mark in another. Constitutional disease is metabolism which has got out of time, out of place, and out of proportion. What is disease in one organism may be normalized in another. Let us give examples.

The strange process by which the bone at the base of the stag's antlers dies away every year would be a pathological necrosis in other animals, but it has been normalized in deer and allows the antlers to fall off. The remarkable changes that occur in Ascidian larvæ or in tadpoles' tails at the time of metamorphosis would certainly be classed as pathological degenerative processes in other types, but they have been normalized. Similarly, the metamorphosis from the larval to the adult type of architecture is, in many insects, accompanied by inflammatory crises in which phagocytes play an important rôle. The viscid threads by means of which the male stickleback binds together the leaves of plants to make a nest are produced, according to Möbius, by the enlarged testes affecting the kidneys in a semi-pathological manner. There are parallel pathological products in higher animals, but in the stickleback the process has been normalized, and turned to good account. Do not the sea-swifts, which make snow-white nests of the copious secretions of the mouth, suffer from super-salivation, and what shall we say of the 'pigeon's milk' which is formed from a curious degeneration and disruption of the cells lining the crop?

In further illustration of this normalizing of the pathological, we may refer to Poyarkoff's description of the gill-plate sacs in which the embryos of the common freshwater bivalve, Cyclas, are incubated. The embryos

develop in the shelter of the inner gill-plate within little sacs, and the point is that these are in the main due to the activity of leucocytes. In other words, they arise by a process analogous to inflammation. After the embryos are liberated the gill-plate requires considerable patching up, especially as regards its epithelial covering.

Trading with Time

In a preceding chapter we gave illustrations of life's victory over difficulties. The most uninviting corners of the earth and sea are explored and exploited; the most unpromising habitats become comfortable homes; a table is spread in the wilderness; there is sometimes, as we have seen, an amazingly successful recklessness, and in cases like the migratory birds who literally 'know no winter in their year', we are face to face with an achievement which seems not far short of getting the better of Time.

(*A*) **Registering Experience.**—The beginning of the organism's business of trading with time was not far from the beginning of living organisms themselves. We are not sure that a living creature was worthy of the name until it became able to register its experience, until it was able to profit by what happened to it. They say that the bar of iron once struck remembers the blow, which seems to us rather an abuse of metaphor, but, as we believe in the value of metaphor as a scientific instrument, we do not press our objection. We would ask, however, whether the smitten bar of iron, or the jarred crystal, or the jewel whose sanctity was violated, remembers the experience to its own advantage, for that is what the organism does. Its premiums paid to experience are its own best treasures.

This capacity of registering experience and of utilizing that registration in subsequent activities, appears to us to be of the very essence of life. To take an instance that seems simple, though it is probably very difficult, they say that Venus's Fly Trap (*Dionœa muscipula*) when it has been tricked several times in succession by stimuli which bring it no satisfaction (or which do not lead on to the normal sequences to which the plant has been habituated in Nature), will cease to respond to the provocative stimuli. It passes into a state of 'physiological sulks'; it becomes callous to stimuli; and this is the very best thing it could do, short of catching hold of the tantalizing experimenter. It *almost* remembers.

It must be recognized that among the simpler animals, such as Protozoa, Sponges, Zoophytes, Sea-Anemones, Corals, Jellyfishes, Sea-Urchins, Starfishes, and simple Worms, with not very much in the way of what are popularly called 'habits', there is great sensitiveness to stimulus and a remarkable power of somehow registering experiences. A starfish has no nerve-centres or ganglia at all; that is to say, the nerve cells of its nervous system are not concentrated, and indeed they have not sunk beneath the level of the skin; but the starfish has a remarkable power of registering experiences and acting differently because it does so. It has got far above the level of simply 'answering back'. One reaches a higher level, of course, when there is real and effective memory, for we cannot believe in more than vague memory in creatures that have not nerve-centres. For real and effective memory there must be repositories or treasure-houses, such as nerve-centres afford.

(*B*) **Individual Modifications.**—We see then that the

organism has a characteristic power of registering experiences, and the next step in our argument is that these experiences may have lasting effects. Let us take one illustration from the results of imprisonment in darkness. Light, as every one knows, has many effects on the living creature :—it is used by the green leaf in building up organic substances; it makes our pulse beat more quickly; it serves as a liberating stimulus for the development of pigment. These are only three of the many relations between light and life. We inquire therefore with interest into the negative side—the influence of darkness, and we shall refer to Ogneff's very interesting experiments on gold-fishes. He kept them in a roomy tank and with plenty to eat—earthworms and 'blood-worms' (larvæ of *Chironomus*, the harlequin fly)—but *in absolute darkness*. He kept this up for over three years, and observed the modifications that occurred in the fish.

The colour first became black, but in the second year it became golden again, and the reason for this is interesting. To begin with, the dark pigment-cells (melanophores) spread out and covered up the subjacent layer of waste-crystals (iridocytes) which give the gold fish its golden sheen. But subsequently the wandering amœboid cells or phagocytes devoured the dark pigment-cells and thus re-exposed the golden layer.

The changes in the eye were even more interesting. A complete alteration occurred in the structure of the pigment-epithelium of the eye, and there was a complete disappearance of the rods and cones, and of some other characteristic features of the eye. Profound atrophy of the eye occurred in the absence of any functioning, and the fish became totally blind. This experiment is of great

interest, and it should be repeated by some other investigator on some other type. It shows us how much may happen in an individual lifetime. It suggests that an individual fish imprisoned in a perfectly dark cave would become blind. In the next generation the atrophy of the eye would probably be greater, since the offspring would experience the darkness from birth while their parents experienced it only from the date of imprisonment. It is likely that the absence of light-stimulus would inhibit the development of the eye. Thus blind fishes in caves might be accounted for in terms of individual loss through disuse. If the degeneration of the eye continued to increase after the second generation, that would prove the hereditary accumulation of an acquired character. On another theory, blindness might arise in caves as a germinal variation and, being possibly advantageous, become a racial character. A constitutionally blind race would not show any power of getting back its well-developed eyes on re-exposure to light, but a modificationally blind race would.

A drastic change in the surroundings often makes the organism quiver in its inmost parts, and curious modifications, that we do not as yet know the meaning of, are brought about. Thus Ogneff has shown that Axolotls kept in darkness and starved at the same time become blanched—an experiment which may throw some light on the whiteness of some cave animals, such as the Proteus of the Carinthian caves. In the Axolotls the black pigment cells atrophied and were destroyed by the ever-ready body-guard of phagocytes, which carried off the pigment. This goes on not only in the skin, but in some of the internal organs, which also lose their black pigment-cells.

(*C*) **Habituation.**—What is true of the results of environmental influence holds good in regard to function. A sequence of activities often performed leads to the establishment of a habit, which is associated with a structural change in the nervous system. As we say, paths are established along which nervous messages pass swiftly and smoothly. Experiments, such as some of those alluded to in the chapter on "The Ways of Life," show clearly that the individual organism can in various degrees become habituated, and it is plainly advantageous to it to have engrained reactions, tropisms, rhythms and instincts. Ready-made effective answers to frequently recurring questions save time and energy, and often the life of the creature. In many cases there is no time for experimenting or deliberating, the answer must be instantaneous if it is to be any good at all. But this brings us to the difficult fact that it is often with more than individual habituation that the organism gives its ready-made answer—such as passing into hibernation on the approach of winter, or flying south in the autumn. Antecedent to its individual experience, it exhibits the effective reaction.

(*D*) **Transmissibility of Acquired Characters.**—In the case of a Protozoon, such as an Amœba or a Slipper Animalcule, the problem is simple. The unicellular creature gathers experience; its organization is definitely affected; it has learned a lesson. This is not for itself alone but for its race, for it multiplies by dividing into two, and each of the daughter-cells shares in the organization which has, so to speak, learned a lesson. Each new unit can then go on to learn the lesson a little better, and so we have the rudiments of behaviour in these relatively simple living creatures. There is no doubt here that the race profits

by the premiums which the individuals pay to experience.

But when we pass from the unicellulars to the multicellulars the problem changes. There is a differentiation between body-cells and germ-cells, and although the germ-cells do not live a charmed life within the body it is difficult to suppose that experiences registered in the body can affect the germ-cells in such a specific and representative way that the offspring will profit by the experiences of its parent's body. It is possible that deeply saturating environmental influences may affect both body and reproductive organs somewhat similarly. It is possible that very important and frequently recurrent alterations of the ordinary metabolism, which are registered as structural modifications of the body, may sometimes be associated with the formation of characteristic cellular substances which saturate through the body and pass into the germ-cells. Through the germ-cell when it comes to develop, these hypothetical substances may affect the body of the offspring. In point of fact, however, we do not at present know that a structural modification of the body of the parent, impressed from without by some peculiarity of the environment, or brought about through some peculiarity of functioning, can affect the offspring in such a specific or representative way that the parent's modification is transmitted. We do not know that this ever occurs.

Many thoughtful people find it impossible to believe that somatic experiences do not specifically or representatively affect the offspring. How can there be any trading with time worth talking about if the individual gains are not handed on as a legacy to the offspring? But the confidence with which this question is asked sometimes disappears when we ask another—'And the losses too?'

For that would be obviously very disadvantageous, and yet we cannot have the one without the other, the pluses without the minuses.

All biologists are agreed that starving a mother may prejudice the development of the offspring, and that the accumulation of toxins in the body of either parent may have the same effect, but that is not the point of the long-continued and still unended controversy regarding the transmission of somatic modifications (badly called 'the inheritance of acquired characters'). The precise point at issue is this: *Does a structural change in a part of the body, directly induced by use or disuse, or by some change in surroundings and nurture generally, ever affect the germ-plasm in the reproductive organs in such a specific or representative way that the offspring will thereby exhibit the same modification that the parent acquired, or even a tendency towards it?*

We have discussed this question carefully in our *Heredity* and *Darwinism and Human Life*, and we shall not attempt to summarize the pros and cons. It may be of interest, however, to give a short account of what appears to us to be the most careful experimental contribution that has yet been made towards the solution of this crucial biological problem. We refer to Dr. W. E. Agar's experiments on one of the small Crustacea, a Daphnid or water-flea. The condensed narrative is necessarily a little difficult, but it will reward the serious student, not only in its interesting conclusion, but also as a fine example of scientific method.

(*E*) **A Test Case.**—Dr. W. E. Agar studied a curious abnormality—reflexion of the valves of the carapace—in the water-flea or Daphnid, called Simocephalus vetulus.

The abnormality seems to be induced by the nature of the food ingested. Affected animals appear quite healthy and reproduce freely. He found that although individuals were removed to control conditions (of relative normality) before the eggs were laid, the young developing from these eggs exhibit the same abnormality as that which their parents had acquired during their lifetime, as a direct result of their environment. This result has been confirmed over and over again. Females with ripe eggs were also removed from control conditions and put into the particular culture which induces reflexion of the valves. The young developed from these eggs were fully normal, showing the persistence of the effects of normal environment. Subsequent broods of these females in the culture became successively more and more reflexed, i.e. the normality wore off just as the abnormality also does.

In a second set of experiments by raising the temperature (to 28·5°—31·5°C.) the size of the young Daphnids was greatly reduced in their first, and indeed in all stages. The rate of the life-cycle was also enormously increased, the period from the birth of the parent to the birth of the young being fourteen days at 16° and six days at 30°. The number of young per brood was diminished. The important results of the experiment were the following. The specimens developing from eggs laid by parents a few hours after removal from the higher to the lower temperature were almost as small as those born at the higher temperature. The subsequent eggs laid by the same parents, still under control conditions, still remained affected by the smallness-producing conditions, though to a rapidly diminishing extent.

In a third set of experiments a reduction of length was

caused by living in a particular kind of solution. The reduction was found to persist for a short time, and was followed by a reaction.

The experiments illustrate 'parallel induction.' In the first and second sets of experiments, at any rate, individuals placed in abnormal environments in their first stage acquired the definite abnormal features in their own bodies in later stages. Simultaneously, the eggs in their ovaries were influenced in such a way that the young developed from them presented at birth the same abnormality as that which their parents had acquired in their lifetime. It made little difference whether the young developed from eggs laid after removal of the parents to control conditions, or were born in the abnormal environment, so long as the eggs underwent their ovarian growth while the parents were under the influence of the environment. In the subsequent broods of those parents which had been removed to control conditions the effect of the abnormal conditions appeared in rapidly diminishing intensity. In the second generation in control conditions the abnormal effect still persisted (in the first two sets of experiments), but to a very slight degree. In all three sets of experiments a very decided reaction appeared in the third generation.

Mutations, giving rise to new types, are due to a change in the composition in the living unit. 'The other cause of variation—a change in the environment while the living units remain the same—is probably far commoner. Such a change, if effective, will probably result in the formation of unusual metabolic products included in the living protoplasm, and thus the visible external variation produced may have as its immediate cause either the changed environment itself, or the altered protoplasmic inclusions. In

the case of parallel induction, it seems that the environment works indirectly, through the mediation of these (not living) products, which when once formed are not immediately got rid of, but are passed on passively included in the protoplasm of the gamete'. Some (not living) product is included in the egg, passes passively into the body which develops from the egg, and thus produces on the body the same effect as it produced on the body of the parent which acquired the character in question.

Dr. Agar sums up the question of transmissible environmental effects as follows:—(1) A changed environment (in its widest sense) may produce a visible modification in the body indirectly by altering the nature of the metabolic products included in the living protoplasm. These in turn react with the protoplasm, and therefore effect changes in its product, the body. (2) Whenever the environment acts simultaneously on body and gonad a similar alteration in metabolic inclusions of somato- and germ-plasm takes place. (3) These metabolic substances included in the germ-cell naturally pass into the developing body, which, therefore, shows the same modification as its parent did, even though removed from the environment in question. (4) These substances may produce a powerful effect, though present only in minimal quantities. (5) They may be of such a nature as to stimulate the formation of antibodies, thus causing a reaction in later generations.

It is probable that many biologists of to-day would be relieved to find that there is much more truth in Lamarckism than Charles Darwin thought there was when he said 'Heaven forfend us from such Lamarck nonsense'. We have taken the most scientific investigation we know of that bears on this question, and it does not seem to strengthen

the Lamarckian position. It is easy to interpret results as due to the hereditary accumulation of individual gains and losses, which have been acquired under conditions of changed function or changed environment; but when it comes to experimental testing the case breaks down.

(*F*) **Does Experience count for the Race?**—Let us turn back to our study of instincts, with this extremely important question in our minds. It is certain that many animals have an inborn capacity of reacting in a definite and adaptive way to particular stimuli, and a succession of these reactions may be linked together in a very effective piece of behaviour. In some cases at least, as we sought to show, it is possible to give a reasonable interpretation of these instinctive capacities. We can think of them *beginning* as germinal variations; we can think of them *progressing* as germinal variations; we can think of them being most subtly *perfected* in the course of Natural Selection. All this is outside of the hypothesis that the tutelage of experience counts for anything except in the individual lifetime. That individual experience may give a finishing touch to instinctive capacity may be admitted without accepting the view that these individual gains are in any representative way transmissible.

What we have stated is the ordinary Darwinian view, but we must in fairness give a statement of the Mnemic interpretation, according to which the offspring are supposed to benefit directly by the premiums paid to experience on the part of their parents and ancestors.

(*G*) **Mnemic Theories.**—The term 'mnemic', which recalls the more familiar word mnemonic, is applied to the theories of heredity suggested by Ewald Hering, Samuel Butler, Richard Semon and others, according to which

the germ-cells are supposed to treasure up some of the results of the organism's experience, as it were, by unconscious memory, so that when they come to develop they reproduce in some measure the traits which their parents or their ancestors acquired as the result of experience. The idea is that the germ-cells become stored with the latent ' memories ' of past generations, or less metaphorically that the germ-cells are changed or impressed in a definite and specific way by the organism's experiences. Development is in part the ' recollection ' of these germinally treasured ' memories '.

Samuel Butler's view was that an inheritance implies a store of memories and that development is akin to recollection. A newly hatched chick pecks at once and with good effect, because certain cells in the chick remember having superintended pecking before. Part of every individual existed before in the parents and the molecules have a memory of previous experiences.

Let us take as a very interesting illustration E. Bordage's observations on European peach trees transported to Réunion. As has been noticed in similar cases, they dropped their deciduous habit and became—it took some twenty years—*evergreen*. The individual constitution was altered. But the still more interesting point is that when seeds of these pseudo-evergreens were sown in certain mountainous districts with a considerable amount of frost, they produced young peach trees which were also evergreen. European seeds sown in similar places produced ordinary deciduous trees.

It must not be hastily concluded that an interesting case like this compels us to return to the old belief in the transmission of acquired characters—in the form that

belief took before Weismann's scepticism. The change to evergreenness was physiological rather than structural —a change in the rhythm of metabolism perhaps. Moreover it is quite likely that the climatic change operating for many years influenced the germ-cells of the peach along with the whole tree. This is a legitimate theoretical distinction, though it is not, perhaps, of much practical importance.

Let us try to state Semon's central position without using his somewhat bewildering terminology. Every one admits that an organism reacts to many different kinds of external change. It registers within itself its novel experiences. Some of these produce changes in what Semon calls the ' energetic situation ' of the whole organism, and these are supposed to impress themselves in a lasting way on the germ-cells. The impressed effects on the germ-cells are conveniently called ' engrams '. Just as our mind becomes rich in memories of experiences, so the germ-plasm becomes stored with many ' engrams '.

The second general idea in Semon's theory concerns development. When the germ-cell which has been impressed with ' engrams ' comes to develop, a partial recurrence of the ' energetic situation ', which previously acted ' engraphically ', will call forth the latent engrams into expression. Given appropriate stimuli the ' memories ' will stir, and they will influence what is going on, namely the development of the individual.

Let us recapitulate. Year after year a complex influence plays upon the organism and modifies its constitution. The internal ' energetic situation ' is changed and resulting stimuli are supposed to pass to the germ-cells. The corresponding changes in the germ-cells are called en-

grams. When the germ cells come to develop into offspring, these engrams may have an influence—a specific influence. Appropriate liberating stimuli of the nature of the original change in the energetic situation will call forth the latent engrams. This is called 'ekphory'.

In support of his mnemic theory of heredity Semon cites, among other facts, Kammerer's experiments on the Nurse-Toad (*Alytes obstetricans*). Unlike ordinary toads, the female lays her eggs on land, and the male who assists in the process gets them glued on his hind legs. Moreover, the eggs are larger than usual, with more yolk, and fewer in number.

Kammerer kept the toads at a relatively high temperature (25°–30° C.) and thus induced them to seek the water, where the egg-laying and fertilization took place. The gelatinous envelopes of the eggs which had remained sticky and unswollen on land, now swelled up as usual, and as they would not adhere to the male's legs, the eggs developed in the water. After several breeding periods the toads became accustomed to the water; they also laid more numerous and smaller eggs.

But the more important fact is this, that the offspring of the toads showed a change of habits like that of their parents. When they became sexually mature they sought the water, even when kept at the normal temperature, and laid their eggs there. The fourth generation showed a re-appearance of the doubtless ancestral swollen pad on the forefinger of the male, which was absent in the race of nurse-toads with which Kammerer experimented. In Semon's phrase the appropriate stimuli called forth the latent ancestral engrams.

Provisional Conclusion.—It may be that there is

more truth in the Mnemic interpretations than we are personally able at present to recognize, and we have no desire to be dogmatic. But we do not feel that the evidence is convincing.

What then is the state of the case? The individual profits by experience, profits in his protoplasm and cells, in his joints and marrow, in his mind and character. There is no secure evidence, however, that his gains are in any way entailed, or that his losses are minuses to his offspring. Yet the progress of a race or stock looks as if these profitable lessons learnt by the individual did somehow count. Now it is possible that the germinal primordia of various characters, embodied we cannot conceive how in the germ-cells, respond, as flames to tuning-forks, to the lessons which the corresponding actualized characters in the body of the individual are learning. We keep an open mind on this question, but it must be admitted that the present-day facts are mainly, though not exclusively, against this view that particular modifications of the parentage do specifically affect the progeny in the same direction. If this be so, what then remains but a retreat to the original Darwinian position of copious germinal variations—sufficiently copious to ensure a certain number of (selectable) hits amid a multitude of misses?

The question ever returns: What is trading with time good for, if the bodily experiences of the individual do not count for the race? For that is what it comes to. We would suggest that the question requires some re-setting. Our biology is at times too anthropomorphic and at times not anthropomorphic enough. In human affairs we continually think of ourselves as experimenting, trying this and trying that, and finally doing something. We transfer

this idea to the non-rational animals, and we think of them, probably aright, as trying this and trying that, and finally doing something. We carry this idea down and down, and probably it is much truer than many naturalists think, but we doubt whether it is by thinking of adult organisms that we shall understand what trading with time really means.

The suggestion we wish to make is this. No one will dispute the statement that an Amœba may profit by its experiences and may make experiments 'in the light of' these experiences. Now it must be remembered that the germ-cells or gametes are not ordinary cells; they are individualities, organisms, creatures, who live and multiply, who struggle and combine, who are repositories of multiplicate inheritances adjusting themselves *inter se* in the most momentous of organic compromises. Now it may be that these gametes—neither simple cells nor portmanteaus of hereditary items, but unified 'creatures', experiment not fortuitously, but artistically, not at random, but with a purpose.

The Living Past.—In any case, one of the strongest impressions that we get from the study of organic evolution is that of the persistence of the past in the present. In a manner inconceivable to us, save through the analogy of memory, the germ-cell garners the long results of time. To some extent in the development of organs in the individual there is a recapitulation of stages which correspond to long chapters in the evolution of the race. And just as we recognize traits of their wild lineage in our domesticated animals, so in a wider field we see the individual's organic reminiscence of primeval days and a recrudescence of ancestral wounds. In ourselves we are only too well

aware of these 'palæo-atavistic' qualities. There is a terrible truth in Walt Whitman's picture of man emerging 'stuccoed all over with reptiles and quadrupeds', and in Tennyson's picture of 'Reversion ever dragging Evolution in the mud'. As Prof. Stanley Hall says:

'We are influenced in our deeper, more temperamental, dispositions by the life-habits and codes of conduct of we know not what unnumbered hosts of ancestors, which like a cloud of witnesses are present throughout our lives, and our souls are echo-chambers in which their whispers reverberate'.

The idea of the living past is familiar in connexion with those vestigial structures, like the teeth in whalebone whales, which persist in many animals as tell-tale evidences of remote ancestry—like the unsounded letters in words or the superfluous flaps and buttons in our clothing which once had a functional significance. Our own body is a veritable museum of relics—some (like the notochord) disappearing in embryonic life, others (like the Eustachian tube) persisting in greatly disguised form, others (like the third eyelid) remaining as dwindling vestiges, and others (like the vermiform appendix) not merely outliving their usefulness, but proving themselves dangerous anachronisms.

It goes without saying that the mere persistence of dwindling organs and of habits that have become anachronisms, is not evidence of misadaptation. The useless teeth of the baleen whale, the unseeing eyes of many cave-animals, and the now meaningless relics of wild habits which many domesticated animals exhibit, present no particular difficulty. They are the vanishing vestiges of characters that were once effective and adaptive. This remains a satisfactory answer—except to those who expect a perfect

cosmos—even when it is pointed out that vestigial organs are often very variable and apt to be seats of diseases (witness appendicitis), and that anachronistic habits form part of what men call crimes.

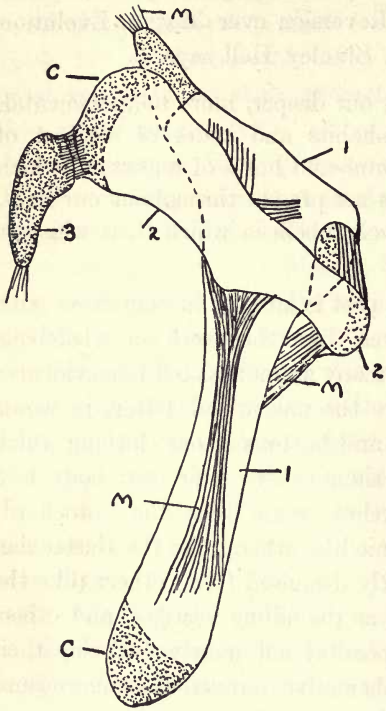

FIG. 93.—Vestigial hip-girdle and hind-limb of a whale. 1, Vestige of pelvis or hip-girdle; 2, Vestige of thigh-bone or femur; 3, Cartilage corresponding to the tibia. The closely dotted parts are cartilage. The dotted line crossing 2 shows the contour of the pelvis; M, muscles attached to these pieces of skeleton. (*After* Struthers.)

None but the unimaginative can fail to be impressed by the sight of the pelvic bones of a large whale. Dwindling relics they are of originally huge hip-girdles. They may be connected with adjacent muscles—a tail muscle, the genital muscles, and a trunk muscle, but they are practically of no moment. Röntgen ray photographs show that they still retain, however, the characteristic internal architecture of bone. Sometimes, as the figure shows, there are vestiges not only of the pelvis (which some say is represented only by the ischiac portion), but of femur and tibia as well. Careful measurement made by Willy Augustin

of the pelvic vestiges of the Finner (*Balænoptera physalus*), the Blue Whale (*B. sibbaldi*), Rudolphi's Rorqual (*B. borealis*) and the Humpback (*Megaptera boops*) show that the bones, like many vestigial structures, are in a state of considerable variability.

We have given two figures of a very interesting and puzzling structure connected with the roof of the brain in Vertebrates. From the region known as the 'tween-brain or optic thalami there is a dorsal up-growth, usually con-

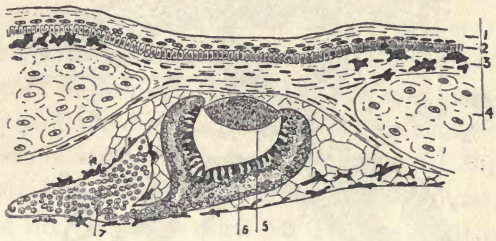

FIG. 94.—Vertical section showing the pineal eye of the adult slow-worm, Anguis fragilis. (*After* Hanitsch.) 1, Cuticle; 2, Epidermis; 3, Connective tissue; 4, Parietal bone of the skull; 5, Lens of pineal eye; 6, Wall of pineal eye; 7, Epiphysis or upgrowth from the brain. It is here continuous with the stalk of the pineal eye. According to Hanitsch, the pineal eye in the slow-worm is sensitive to changes of temperature.

sisting of two parts, a pineal organ or epiphysis proper, and a parietal organ, which generally springs from the epiphysis, but may have an independent origin in front of it. Perhaps they were originally the right and left members of a pair. The parietal organ is often atrophied, but in some cases, especially in Reptiles, it is terminally differentiated into a little 'pineal body.' In the New Zealand 'lizard' (Sphenodon) and in the slow-worm (Anguis) it shows distinct traces of eye-like structure.

In the lamprey, both the epiphysis and the parietal organ show this. Above Reptiles the pineal stalk is short and its terminal portion is glandular. The epiphysis is occasionally absent in Mammals (e.g. some Cetaceans), and the pineal body is absent in the dolphin and Dasypus. According to some authorities, the pineal body was primitively an unpaired median, upward-looking eye; according to others, the optic function is a secondary transformation.

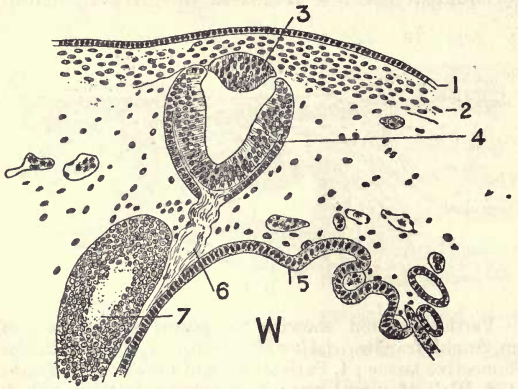

FIG. 95.—Section showing developing pineal eye of Sphenodon. (*After* Dendy.) 1, Epidermis; 2, Dermis; 3, Lens; 4, Wall of pineal eye; 5, Choroid plexus of dorsal sac, on the roof of the third ventricle of the brain; 6, Nerve of pineal eye; 7, Pineal sac.

For it not infrequently happens that a dwindling structure, tending to become vestigial, may become secondarily specialized. Thus the vestigial hairs on the lips of some whales have a quite extraordinarily rich innervation.

It must be frankly admitted that many of the examples that used to be given of the re-assertion of long-lost ancestral characters were insufficiently criticized, and the list of so-called reversions has been remorselessly thinned by the more modern students of inheritance. Sometimes,

however, it does seem as if the return to an old-fashioned condition was best explained by the hypothesis of the re-awakening of an ancestral trait which had lain latent for many generations.

In other cases it seems more likely that some derangement of development has resulted in a suggestion of an ancient condition without there being any re-awakening of any particular ancestral item in the inheritance. Probably this is the case with most of the two-toed horses that crop up. But some of them are strongly suggestive of more than this. Thus Prof. K. Skoda, of the Veterinary College in Vienna, describes a case where each fore-leg bore beside the normal single digit (No. III) a second. This second (No. II) had three joints, but did not reach the ground. There was a metacarpal (or palm-bone) for this extra digit, but it was largely fused with the ordinary metacarpal of No. III. The usual No. IV. free splint or metacarpal was present, and there seemed to be actually hints of a minute metacarpal No. I. Especially when we look into the details of a case like this does it seem difficult to dissociate what occurred from all relation to the ancient polydactyl.

To some minds it seems very inconsistent to credit the germ-plasm at one time with great stability, and at another time with great power of change. But there is really no paradox here, for every thinker with a lively intelligence shows the same combination of qualities—holding by fundamental principles, yet restlessly experimenting with an open mind. So the germ-plasm in its own fashion proves all things and holds fast that which is good. Moreover, it is quite likely that the varying or mutating occurs periodically. Just as we have an alternation between speculation and

dogmatism, between liberal and conservative moods, so the germ-plasm may have what correspond to originative and fixative moods.

As an instance of the stability of the germ-plasm, even when violently treated, we may take Dr. D. D. Whitney's investigation of the effect of alcohol on generations of Rotifers. He studied four strains of parthenogenetic Rotifers, originally descended from one female, for twenty-eight successive generations. One strain was kept as a control, and the other three strains were kept in a quarter per cent., a half per cent., and one per cent. of alcohol. The rate of reproduction was lessened in the alcoholic strains and the resistance power was lowered. In the eleventh to fifteenth generations of the one per cent. alcohol strain, the individuals showed a decidedly lower resistance power. They exhibited a markedly increased susceptibility to copper sulphate which was used as a test of resistance. The result showed, then, the evil effects of alcohol. But whether it showed the *hereditary* evil effects or not remained to be seen.

When the alcohol was removed in generations eleven to twenty-two, the rate of reproduction increased noticeably in the very first generation, and in the second equalled that of the control strain. Individuals of the second generation after the alcohol had been removed were no more susceptible to copper sulphate than those which had never been alcoholized. The general conclusion is that the grandchildren possess none of the defects caused by alcohol in the grandparents. The alcohol, in the small percentages used, affected only the body-tissues of the Rotifers, which is not, of course, to be interpreted as meaning that chronic alcoholism in man may not affect the germ-cells. Dr. Whitney

also points out that if the Rotifers were subjected to the alcohol solution indefinitely, generation after generation, the race would probably become extinct. The alcohol lessens the rate of reproduction and it *may*, in the course of time, progressively weaken the germ-cells. What was proved, however, was that ' if the alcohol is removed it is possible for the race to recover and to regain its normal condition in two generations, thus showing that the germ-substance is not permanently affected by the alcohol ' so far as the experiments went. In any case we have a good instance of the stability of the germ-plasm.

It is only fair, however, to cite a case on the other side, indicating susceptibility. Dr. Charles R. Stockard made experiments for three years in intoxicating male guinea-pigs by inhalation of alcohol (which does not spoil their stomach), and reached the important conclusion that an alcoholized male guinea-pig almost invariably begets defective offspring even when mated with a vigorous normal female. The effects were manifest in the second generation animals as well. ' The poison injures the cells and tissues of the body, the germ-cells as well as other cells, and the offspring derived from the weakened or affected germ-cells have all of the cells of their bodies defective.'

Dentition of Shrews.—Let us take a somewhat unfamiliar illustration of a persistent relic. It is well known that in ordinary placental mammals with various kinds of teeth (heterodont as it is called), there are never more than three pairs of incisors. There is thus a gap between all ordinary mammals and the old-fashioned Polyprotodont Marsupials, such as the Tasmanian Wolf or Thylacine, which has four upper incisors, and the Bandi-

coot (*Perameles*) which has five. Now a study of the development of the teeth in shrews led Augusta Ärnbäck-Christie-Linde to the very interesting discovery, that there are more than three incisor germs in both jaws of *Sorex araneus*, and probably also in the upper jaw of *Neomys*. These extra incisor germs in the Shrew are apparently useless relics—vestigial structures without any function. They come and they go without attaining full development. 'They are', the discoverer says, 'undoubtedly inherited from distant ancestors, which consequently were to be found among polyprotodont (and heterodont) mammals'. As regards the number of incisor teeth it seems as if the Shrews bridged the gap to which we alluded above. In any case, these extra incisor germs seem to illustrate our present point—of the long lingering of structural relics which have outlived their use.

In the inner upper corner of our eye there is a minute half-moon-shaped fold, the *plica semilunaris*, a most interesting item in the museum of relics which we carry about with us in our body. For it corresponds to the third eyelid (in whole or in part) which is well-developed in most mammals and helps to clean the eye. It is vestigial not only in Man, but in Monkeys and in Cetaceans. Its practical absence in the Cetaceans is compensated for by the continuous washing of the eye with water. In the other cases the frequent movements of the upper eyelid must make up for the vestigial state of the third eyelid. It is a very old structure, a venerable relic, for it is the 'nictitating membrane' that is flicked across the eyes of Birds and it is also represented in most Reptiles.

It may be profitable to pursue the matter a little further. The *plica semilunaris* sometimes includes in man a minute

cartilage—a tell-tale cartilage. In white races it is a great rarity, occurring in less than one per cent. Giacomini found it in four cases out of five hundred and forty-eight whites. But he found it twelve times in sixteen coloured people, and Adachi found it five times in twenty-five Japanese. More recently Dr. Paul Bartels examined twenty-five South African natives (eight Hereros and seventeen Hottentots) and found the tell-tale cartilage in twelve. The cartilage is found in all Apes and Monkeys, and although no living Ape or Monkey is ancestral to Man, the cartilage is a Simian feature, persisting in Man since the remote period when the human stock diverged from the Simian. The facts show that some races are in this instance as in others, more theromorphic than others—more conservative of their historical relics.

One has, of course, to be careful in using this interpretation of peculiarities as atavisms. It is probable that in some cases all that we are justified in saying is that a variation occurs which happens to be along very antique lines. To take an example, the teeth of mammals begin as ingrowths of the (ectodermic) epithelium into the (mesodermic) connective tissue of the gum, whereas the teeth of sharks and skates and other Selachian fishes begin as papillæ of the mesoderm which grow up into the epidermis. The teeth of Selachians are just transformed scales, turned to a new use. But it is a remarkable fact that the Selachian or placoid mode of tooth development does occur in Bony Fishes, tailed Amphibians, and in the crocodile. Röse has seen hints of it in the human embryo, and not long ago (1911) Adloff found in a human embryo, of about nine weeks, a freely projecting epithelial papilla lying beside a normal tooth-germ. He regarded it as an atavistic

rehabilitation of the oldest mode of tooth-development.

Amphibian Scales.—Sometimes it seems quite legitimate to recognize a structure as a relic although we are not aware of the precise affiliation. Every one knows that almost all amphibians are naked-skinned or scaleless in great contrast to the scaly Reptiles. It is also well known that some of the ancient extinct Amphibians, the Labyrinthodonts or Stegocephali, were armoured. Therefore it is interesting to find in the most old-fashioned stocks of living Amphibians, namely the burrowing Cæcilians, that there are transverse rows of thin calcified scales imbedded in the dermis or under-skin. Moreover, in a few rare cases among tailless Amphibians, there are bony scales in the skin. Thus in *Ceratophrys dorsata* there is a bony shield on the back which arises from the confluence of a large number of small ossifications in the dermis. It is very unlikely that this can mean anything but a retention of the ancestral armour. Not less interesting, though less secure, is Margarethe Kressmann's interpretation of numerous papillæ that occur all over the lower layer of the dermis in *Siren lacertina*, the American mud-eel. Each consists of firm connective tissue and is usually tipped with a mantle of pigment. They project into the more superficial looser layer of the dermis and are quite hidden from the outside. It seems reasonable to interpret them as dwindling vestiges of the ancestral armature.

The Egg Tooth.—At the tip of the bill of many unhatched young birds there is a horny knob which is called the egg-tooth. It has nothing whatever to do with teeth, of which, as separate structures, no living bird is known to show any hint (the alleged cases of tern, etc., having broken down); but it is interesting in several ways. If it

is of use in breaking through the egg-shell to liberate the young bird, which seems, in some cases at least, to be very doubtful, then it is one of those structures which are used only once. As every one knows, it usually falls off soon after hatching.

This fact suggests that it may not be a special structure that has evolved on a line of its own, but the last relic of an old set of structures, retained because of its utility while all the others have gone. Some recent observations by B. Rosenstadt suggest that the egg-tooth of the upper jaw and its corresponding vestige on the lower jaw, may be relics of an ancient armature, older than the horny sheaths we are familiar with on the bird's jaws. In the first place they become horny in the embryo before there is any other cornification on the jaws. In the second place, the process of horn-making in the egg tooth is different from that elsewhere. Each of the skin cells concerned turns wholly into horn, nucleus and all, whereas in ordinary cases, as in the horny sheaths that make the bill, only the mantle of each cell is turned into horn. This is a technical point, but it is of interest in suggesting that the egg-tooth is a very ancient relic indeed.

Whales' Hairs.—Let us look at the fact of whales' hairs. If we could understand these, we should have a master-key in our hand. The points are three. (1) The ancestry of Cetaceans is unknown, but they are quadrupeds and mammals none the less that the remains of the hind-limbs are buried, and that their hairs are reduced to a minimum. It is possible that whales were evolved from scale-covered Mammals, which took to aquatic life. The slight resemblance of the whale's flipper to that of the extinct Ichthyosaurian reptiles cannot mean much; for

the flipper-type must have arisen *de novo* in the Cetaceans. It is a specialized transformation of a typical mammalian limb, just as the skull is a specialization of a typical mammalian skull.

(2) Although the divergence of Cetaceans from a terrestrial stock must have taken place very long ago, the loss of hair may have been very gradual, or it may have occurred brusquely, by a mutation such as we see in ' Chinese dogs '. It is a remarkable fact that they seem never to disappear altogether. Although the inexperienced eye may see none, there is probably no species entirely without them. Dr. Arnold Japhen recently examined five kinds of baleen whales and six kinds of toothed whales, and found hairs about the lips of them all. Therefore we must admit that the capacity of forming hairs remains still in the Cetacean skin, that, in some way or other, the potentiality of hairs persists as a dwindling relic as part of the inheritance. It is very interesting to find that apart from their great reduction in number, the hairs show distinct signs of retrogression. The hair-muscles and the sebaceous glands have gone, the hair shaft is greatly reduced, what is called the root-sheath is simpler than usual, and there is no hair casting.

(3) On the other hand, we find in regard to whales' hair an illustration of what has often occurred in the course of evolution—that vestigial structures may be utilized, indeed specialized, even when they are very much reduced. It seems, metaphorically speaking, as if the organism sometimes saved its historical relics just as they were disappearing by discovering some utilitarian vindication of them. For these small retrogressed hairs on the whales' lips exhibit at the same time a remarkable specialization, namely in their rich supply of nerve-fibres

and in the way these end in the hair-follicle. There may be four hundred nerve-fibres to a single hair, so that if there are twenty-five hairs on the chin region, there are

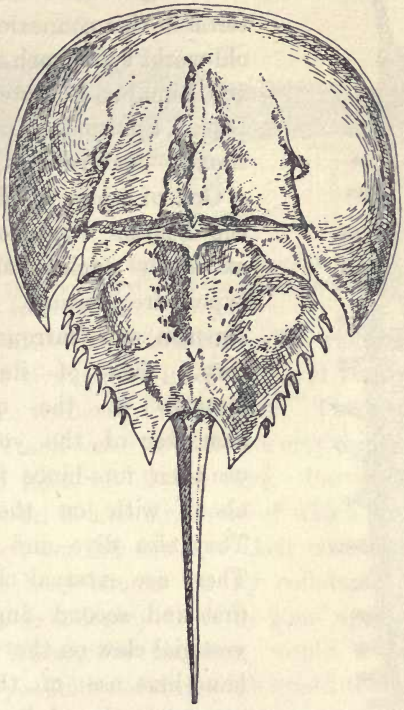

FIG. 96.—King Crab, Limulus, seen from above. It is an archaic type, a veritable 'living fossil,' the sole survivor' of the ancient race of Palæostraca. The figure shows the horseshoe-shaped cephalothorax shield, bearing lateral and median eyes; the abdominal shield; and a spear or telson projecting behind. (From a specimen.)

ten thousand nerve fibres. The vestigial hairs seem like specializations of the tactile hairs or vibrissæ which every one knows in a cat's whiskers. In the toothless Cetaceans

at least, it seems highly probable that these richly innervated, though much reduced structures, play some rôle in connexion with food-getting.

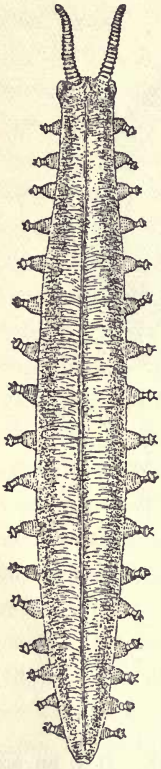

Fig. 97. — Peripatus, an ancient type, in some respects linking segmented worms to Insects. The figure shows antennæ, simple eyes, simple clawed appendages, and an unsegmented somewhat caterpillar-like body. (*After* Balfour.)

Living Fossils.—Of great interest in this connexion are those old-world types such as Peripatus and Limulus, Polypterus and the Dipnoi, Sphenodon and the Monotremes—survivors of ancient races.

One of these living fossils is the hoatzin (*Opisthocomus*), an extremely ancient and isolated type, frequenting the lower Amazon and surrounding territory. One of its primitive features is the quadrupedal character of the young, which use their fore-limbs for creeping about with on the branches. They also dive and swim well. There are external claws on the first and second fingers and a vestigial claw on the third. The hand-like use of the wing is present in the adults as well, who never fly if they can help it. Mr. Beebe notes that 'their method of arboreal locomotion is to push and flop from branch to branch'. Their weakness of flight is doubtless in part due to a curious specialization, that the crop has

become like a gizzard, with thick and muscular walls. This is associated with a unique reduction of the front of the breast-bone, and a consequent lessening of the area for the attachment of the muscles of flight.

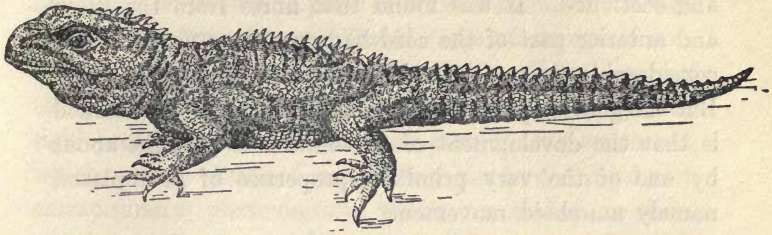

FIG. 98.—New Zealand Lizard, Sphenodon or Hatteria, an archaic reptilian type, sole survivor of the ancient race of Rhynchocephalia. (From a specimen.)

Conservation in Evolution.—We wish to expand the idea of the living past into a general conception of the conservative tendency in evolution. There is, it seems to us, a very literal sense in which we may think of the higher animals as heirs of all the ages. Particularly effective modes of vital behaviour, some of which made a fortune in their day, yet did not save their possessors from utter ruin, have been caught up by collateral relatives and handed on as a legacy from by-gone ages to the higher animals. Where, for instance, would a higher animal be—what possibility of such a life would there be—without a persistence of that most primitive manifestation of life which we call amœboid movement—the ebb and flow of a protoplasmic tide—so familiar to students of biology in amœbæ and white blood corpuscles? How long would a higher animal survive without its body-guard of phagocytes? Nor could it have become what it is, had not its embryonic nerve-cells flowed out into nerve-fibres, just like exploring Amœbæ!

One of Harrison's devices was to excise a small portion of nerve cord from an embryo frog, and to replace this by a cylindrical clot of blood or lymph of the proper length and calibre. After two or three days the embryo was killed and sectioned. It was found that fibres from the brain and anterior part of the cord had grown, or flowed, for a considerable distance into the cord, forming naked threads. But the general point with which we are here concerned is that the development of nerve-fibres is brought about by one of the very primitive properties of protoplasm, namely amœboid movement.

It is very interesting that the only animal types without wandering phagocytes are the Nematodes (some of which at least have stationary phagocytes) and the Lancelets. The Nematode worms do not lead on to anything else; and the Lancelets, though near the base of the Vertebrate branch, are specialized types on a *cul-de-sac* of their own! It appears to us profoundly significant that Man himself in the development of his nervous system, in the repair of an injury to the front of his eye, in the everyday resistance to intruding Bacteria, and in every inflammation, serious or trivial, harks back in his cellular activities to the Amœbæ gliding along on the mud of the pond.

Vitalism

The Purely Physical.—Among the facts with which the student of science has to deal there are many which he calls purely physical—the movements of the earth and the heavenly bodies, the seasons and tides, the sun and the wind and the rain, the weathering of the mountains, the making of the fruitful land, and so forth. The reality

which these facts represent may not be exhausted by formulæ in terms of matter and motion, but for the theoretical purposes of description, and for the practical purposes of anticipation and mastery these formulæ suffice. The facts may be treated as parts of a mechanism, on the view that all are 'merely complicated cases of change of configuration in a system of mass particles'. The processes of the physical order are marked, as every one knows, by their rigid uniformity of routine, their monotonous sequences, which are like chains of iron. They can be described with extraordinary precision—on which we stake our lives every day—by means of formulae which have only a few factors in them. At present, these factors seem to be not more than five—the ether, the electron, the atom, the molecule, and the mass, energy being 'involved in the construction of any of these out of any other'. The question with which vitalists are chiefly concerned is whether these concepts are adequate for a useful description of the activities of organisms—for *a description which will make the facts of life more intelligible*, by showing them to be particular cases of something more general. For that is what 'making a thing intelligible' usually means. It must be quite clearly understood that as material systems in space, organisms 'conform to the laws of the physical universe': gravity affects a bird just as it affects a stone, the properties of a hydrogen atom are the same whether it forms part of a scholar or of his midnight oil, capillarity is as inexorable in a blood vessel as in a glass tube; but what the vitalist says is that all the available knowledge of chemical and physical happenings within the organism does not begin to answer the distinctively biological questions.

The Animate.—That the animate order of facts transcends in some way the purely physical seems to some minds, and to certain moods of other minds, almost self-evident. The world of life is full of individuality, of spontaneity, and apparent purposiveness. Living creatures often make fatal mistakes when the environment is too much for them, but in their normal surroundings what is characteristic is their effectiveness of response, making for self-preservation and betterment. They are genuine agents, trying, or seeming to try, one reaction after another until they find the one which is most effective ; they profit by experience.

It is necessary, however, to face the objection that these qualitative criteria of livingness are manifest only in the higher reaches of the animal kingdom, and illustrate the compounding and elaborating that goes on in evolution. The plant seems less animate than the animal, the coral less animate than the bird. And we have already referred to such difficulties as are presented by latent life and local life, by the survival and development of a minute fragment of an egg, and by the fertilization of a frog's egg by a pin's prick. We must not take selected instances of life's apartness ; we must consider vital phenomena all along the line.

Argument from everyday Functions.—When we take counsel with the physiologists and inquire into the contraction of muscles, the irritation of nerves, the digestion and absorption of food, the process of respiration, and the filtering of blood by the kidneys, we find that many chemical and physical processes are involved, but that it has not yet been found possible to give a continuous physico-chemical description of any total vital function. We can isolate off portions of a function and watch them occurring in a test-tube away from the living body alto-

gether, but we cannot re-combine our analyses so as to account for the whole.

It is not merely what happens, but the way in which it happens, that we have to consider. If we inquire into the passage of digested food from the alimentary canal into the blood, or the interchange of gases in the lungs, or the filtering that goes on in the kidney, we certainly find that these involve physico-chemical processes, and we detect in their occurrence nothing that contradicts the principles of physics and chemistry; *and yet* the physico-chemical formulæ do not suffice for a complete description of the vital function. They do not quite fit; the living cells make a difference—a difference which we have at present to accept as a fact.

Every year we know more about the physical and chemical processes that occur in living bodies, but it does not seem as if the physico-chemical explanation of vital functions was coming any nearer. We do not know what the future may have in store; but we must take things as they are, and there is surely significance in the fact that increased knowledge of physiological chemistry and physiological physics has brought the distinctively vital into stronger relief. It has not made the distinctively vital more intelligible; that is, it has not shown it to be a particular instance of something more general.

Treating the organism as a machine has led to great clearness in regard to the big transformations of energy that go on in the body. Without Chemistry and Physics applied to the living body, what would be our understanding of respiration, of animal heat, of muscular work, or of the significance of the various kinds of waste? And yet what works well as an engine of research, does not suffice

for a formulation of the facts—of the way in which the great workshop of the body is regulated, of the way in which the different functions are adjusted to every varying need, of the way in which they work into one another's hands, so that a unified effective life results. To take one instance, it is no longer a difficult physico-chemical problem to account for the 'animal heat' of the living body (or for a large fraction of it, at any rate), but this does not help us much to account for 'warm-bloodedness'; that is to say, for the regulation of heat-production and heat-loss, so that the temperature of the body of the bird or the mammal remains approximately constant whatever the outside temperature may be. Much is known in regard to the so-called 'thermotaxic mechanism', but the more we know the further off it seems from mechanical explanation.

If no everyday function of the body has found complete re-description in physico-chemical terms, it follows *a fortiori* that we are not within sight of an explanation of such fundamental vital processes as growth and reproduction. As we have already seen, organic growth is no process of passive accretion, it is selective and integrative. The new material is incorporated and unified; what is added on is related essentially, far more than topographically, to what is already present. The growth is a reproduction of the specific organization and of no other.

It may seem strange to assert that even if we had a complete record of all the transformations of matter and energy that go on within the body in all its everyday functions, we should not be answering the biological questions as to the activity of the creature as a whole: What is the 'go' of this animal, how does it keep agoing, how do the various functions work in a variable way into one

another's hands, how are they co-ordinated in a harmonious result, how are they adjustable to changeful external conditions? Even a complete ledger of the osmotic and capillary processes, the oxidations and reductions, the solutions and fermentations, would not furnish the kind of description the biologist wants.

We must bear in mind the extraordinary complexity of the problem of the everyday life of any common animal. For what is a creature but a huge army with battalions which we call organs, brigades which we call systems? It advances insurgently from day to day always into new territory—often inhospitable or actively unfriendly; it holds itself together, it forages, it makes good its own losses, it even recruits itself, it pitches a camp and strikes it again, it goes into winter-quarters, it retreats, it recovers itself, it has a forced march, it conquers. What the biologist wishes is a description of the organism's daily march which will not ignore the reality of the *tactics*—the intra-organismal tactics.

In addressing the Physiological Section of the British Association in 1909, Professor E. H. Starling said:—

'In his study of living beings the physiologist has one guiding principle which plays but little part in the sciences of the chemist and physicist, namely, the principle of adaptation. Adaptation or purposiveness is the leading characteristic of every one of the functions to which we devote in our textbooks the chapters dealing with assimilation, respiration, movement, growth, reproduction, and even death itself'.

Now adaptation or purposiveness requires a historical explanation; it is a supra-mechanical concept. It is true

that it applies, in a measure, to a machine, but a machine is the embodiment of a human purpose. It is an elaborated tool, an extended hand, and has inside of it a human thought.

The Argument from Animal Behaviour.—The inadequacy of a physico-chemical account of vital activity becomes even more obvious when we pass from the everyday activities of the body to a connected series of animal activities—to animal behaviour.

Let us return, for instance, to the newly hatched microscopic larva of the liver-fluke, of so much practical importance to sheep-farmers (see p. 307). It has no organs in the strict sense; it has only a few cells altogether; it has no hint of a nervous system. It is covered with cilia, and has energy enough to swim about for a day in the waterpools by the pasture. It comes in contact with many things, but it responds to none, until haply it touches the little freshwater snail (*Lymnæus truncatulus*)—the only contact that will enable it to continue its life. To this it responds by working its way in at the breathing aperture, and within the snail it goes through a complex series of multiplications and metamorphoses, the upshot of which may be that a sheep becomes infected with a young liver-fluke. The life-history is dramatic, the risks of failure are enormous; our point is the delicate adaptation of a brainless organism to the one stimulus which will enable it to continue its life. This seems to us to be far beyond all possibility of mechanical description; it requires a historical explanation.

What we have just alluded to is no rare curiosity; it is a frequent and characteristic feature in animal behaviour that the organism is historically tuned to be a receptor

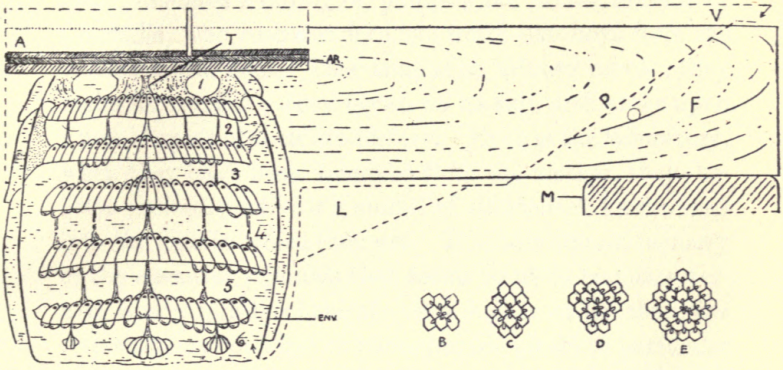

FIG. 99.—Nest of hornet, Vespa crabro, in vertical section. It was suspended from a slate roof, AR. The top of the primary central support is seen at T. There are six tiers of combs (1–6). Round the central comb of the sixth tier, there are four combs, the structure of which is shown at the side, B C D E. V, the entrance. P, the road to the nest, along the beam F, is marked by the dotted line. A short cut has been formed at L, which represents two triangular paper screens. M, part of the gable wall. As the situation was a very warm one, the wall of the nest had only one thin envelope (ENV). (*After* Janet.)

to particular but absolutely indispensable stimuli which may not occur more than once in the life-history. The freshwater mussel, as we have already mentioned, carries her young ones in her outer gill-plate, and does not set them free unless a stickleback or a minnow or some other such fish is in the immediate vicinity. When the fish comes near, the mother mussel, whom it is no libel to call 'acephalous', liberates a crowd of pinhead-like larval mussels or Glochidia, who rush out into the water like boys from the opened school door. They snap their minute valves; they make for the fish; they fasten on its skin and enter upon a new chapter of their life-history. Even in the laboratory, when they have been removed from the mother, they become excitedly active if a morsel of stickleback be dropped into the dish in which they are. It is this organic memory of the essential stimulus that seems to us to be characteristic and supra-mechanical—of a higher order than the responsiveness of wires or photographic plates to particular kinds of rays. It is a sensitiveness gained or invented by the creature in the course of its racial evolution and registered in the constitution. Though simpler, it is as well marked in the absolutely brainless larva of the liver-fluke as in the larval mussel which has the beginnings of a nervous system; in a small-brained, predominantly instinctive creature like a bee as much as in a big-brained, predominably intelligent creature like a bird. We find analogous kinds of behaviour at all levels of nervous organization. The worker-bee leaving the hive for the first time enters a new world with confidence and proceeds to gather honey from difficult flowers, being 'to the manner born'. We have referred to the definite proof that a young swallow which leaves Britain for the South at the end of

Summer may return the following Spring to the farmsteading which was its birthplace. The question is: Does the return of the swallow differ from the return of a thrown boomerang in kind or only in degree; that is to say, Does it require different fundamental concepts for its interpretation?

We wish to emphasize the fact that the same sort of behaviour—requiring historical explanation—occurs at all levels of organization, even when there is no question of brains at all. It is distinct from the 'soul and body' problem. Dr. Driesch, who stands as the foremost protagonist of modern vitalism, got to his strong convictions by experiments on egg-cells, where there are no data as to mental processes. The problem of the autonomy of life would confront us even if—to make an impossible assumption—there were no animals in the world at all, only plants and us—Jack and his bean-stalk, in fact.

Migration of Eels.—As an illustration of the problem of vitalism let us take the migration of eels, which has been recently discussed in this connection in a masterly article by Mr. E. S. Russell ('Vitalism', *Rivista di Scienza*, April, 1911). It is a very useful case, because the eel has a brain of a very low order, and we are not warranted in using in regard to it the psychological terms which are indispensable in the case of the more intelligent birds and mammals (see p. 458).

The eels of the whole of Northern Europe probably begin their life below the 500-fathom line on the verge of the deep sea away to the west of the Hebrides and Ireland, and southwards to the Canaries. The early chapters of the life-history remain obscure, but the young larva rises to the upper sunlit waters as a transparent, sideways-flattened,

knife-blade-like creature, about three inches in length, with no spot of colour save in its eyes. It lives for many months in this state—known as a Leptocephalus—expending energy in gentle swimming, but taking no food. It subsists on itself, and becomes shorter and lighter, and cylindrical instead of blade-like. It is transformed into a glass-eel, about two and a half inches long, like a knitting needle in girth. It begins to move towards the distant shores and rivers. In some cases it may take more than a year to reach the feeding ground—those that ascend the rivers of the Eastern Baltic having journeyed over three thousand miles. Their ranks are thinned, but large numbers succeed in finding the estuaries, and the passage of millions of elvers up our rivers is one of the most remarkable sights of Spring. There is a long period of feeding and growing in the slow-flowing reaches of the rivers and in the fish-stocked ponds. But there is never any breeding in fresh water, and after some years a restlessness seizes the adults as it seized the larvæ—a restlessness due, however, to a reproductive, not to a nutritive motive or impulse. There is an excited return journey to the sea—they don wedding garments of silver as they go and become large of eye. They appear to migrate hundreds of miles, often at least out into the Atlantic to the verge of the deep sea, where, as far as we know, the individual life ends in giving rise to new lives. In no case is there any return.

Let us consider in particular the penultimate chapter, the migration from the rivers to the distant spawning grounds. Like many other fishes, the eel requires for spawning very definite conditions of depth, salinity, and temperature. The North Sea will not serve, for it is too shallow; nor the Arctic Ocean, for it is too cold. What can the Machine

Theory of Life make of a story like this ? What can the physiology that is only applied physics and chemistry tell us ? It can tell us, for instance, a most useful thing to know, how the energy for the journey is obtained from chemical explosions of oxidizable material in the muscles of the eel's body. It can tell us some of the steps in the making of this fuel out of the eel's food. It can tell us that the muscles are kept rhythmically contracting by nervous stimuli ; that the advent of sex-maturity often alters an animal's reactions to external stimuli ; and so on for a whole volume. It is all interesting and indispensable, but it does not really help us much in trying to understand the migration of the eels to the distant spawning grounds. Even if an omniscient chemist and physicist could give an account in his own language of all the physical and chemical happenings that occur in the eel's body from the time it left the pond to the day of its death, that would not make more intelligible to the biologist the concatenation of all these into the unified adventure of migration.

'To the chemist', Russell says, 'confronted with this problem, there is no fact of migration at all ; there is only an intricate enravelment of chemical reaction. To the biologist the fact of migration to a particular region for a particular purpose is cardinal'.

If it be said that one can picture, in dreams at least, a torpedo so delicately adjusted, that it descended rivers, went out to sea, kept off the rocks, turned corners, and did not explode until it could do so effectively in an area of appropriate stimulation, the answer must be that this mechanism is still a very hypothetical construction, and that if it were constructed it would not be a fair sample of

the inorganic world. For obviously it would have a human idea and a human purpose inside of it—the very essence of its construction. But more than that, the eel has made itself what it is in the course of ages; it has traded with time; it has evolved. And again, the hypothetical torpedo does not, in its final explosion, start a crowd of potential torpedoes, which is what the eels do before they die.

But if the mechanistic account of the eel's migration is unsatisfactory, is the vitalistic one—or, as we prefer to say, the biological one—any better? What light has biology to throw on the remarkable story? Only this, that we can relate the particular case of the eel to what we know of organisms in general, that they are historical beings, determined by their past—their own past and that of their race. The eel's inheritance is a treasure-store of the ages, a registration of many inventions. Non-living things have no history in this sense; we cannot say that they have profited by experience. In the organism, as Bergson says, the past is prolonged into the present. Thus we pass on to a new level of explanation or interpretation, which is historical—in a sense different from that implied when we give a so-called historical interpretation of the present state of the Alps. As Professor W. K. Clifford put it:—

'It is the peculiarity of living things not merely that they change under the influence of surrounding circumstances, but that any change that takes place in them is not lost but retained, and as it were built into the organism to serve as the foundation for future actions. . . . No one can tell by examining a piece of gold how often it has been melted and cooled in geologic ages. . . . Any one who cuts down an oak can tell by the rings in its trunk

how many times winter has frozen it. . . . A living being must always contain within itself the history, not merely of its own existence, but of all its ancestors.'

As Bergson maintains, it is distinctive of the organism, as of ourselves, that :—

'Its past, in its entirety, is prolonged into its present, and abides there, actual and acting'. 'Continuity of change, preservation of the past in the present, real duration—the living organism seems to share these attributes with consciousness'.

Argument from Development.—When we observe the development of an animal actually going on, in almost perfect transparency, as in the moth *Botys hyalinalis*, we get an impression of something very unlike anything else in the world. From a minute clear drop of living matter lying on the top of the yolk we see in the course of twenty-one days the development of the chick—the gradual emergence of the obviously complex from the apparently simple. It seems far away from mere machinery ; it is more like an artist painting a picture. We get the same impression when we look into details, such as the making of the silk-like threads that compose the familiar skeleton of the bath sponge. Large numbers of secretory cells called spongoblasts group themselves in double file in the middle stratum of the sponge, as if some unseen captain marshalled them. Up the middle of the double file spongin is secreted, made at the expense of the contributors, and the many individual contributions coalesce in a sponge-fibre. By combining the images that we get from sections at various stages we can, in a sense, see the replacement of a piece of cartilage by bone—the sappers and miners

called osteoclasts who clear the ground, and the builders called osteoblasts who build up the new construction—all working like busy ants. We feel that this transcends mechanical categories. Reference has already been made to the quite extraordinary series of events that is witnessed when a larval insect, such as a fly, goes through its metamorphosis—the larval body breaking down into debris, the new body being built up out of the ruins on a very different architectural plan. The central wonder of development is the general process of differentiation, the realization of the inheritance, but this is enhanced by many accessory facts: there is the remarkable power the embryo often shows of righting itself when the building materials of its edifice have been artificially disarranged; there are interesting 'regulation phenomena' by which it adjusts itself after disproportions have been artificially induced; there are the strangely circuitous paths, reminiscent of ancient history, by which it reaches its goal; there are the widely different ways of securing the same results.

The vitalistic argument from the facts of development has found its finest expression in the work of Dr. Hans Driesch, who was led to the conclusions of his *Science and Philosophy of the Organism* by a brilliant series of embryological experiments. His arguments based on the study of morphogenesis, or the development of form and structure, are too technical for our present discussion (we have given a résumé of them in *The Hibbert Journal*, January, 1912, in an article from which we have borrowed freely); we cannot do more than indicate his main thesis.

'Life, at least morphogenesis, is not a specialized arrangement of inorganic events; biology, therefore, is not applied physics and chemistry: life is something apart,

and biology is an independent science'. . . . 'There is something in the organism's behaviour—in the widest sense of the word—which is opposed to an inorganic resolution of the same, and which shows that the living organism is more than a sum or an aggregate of its parts. . . . This something we call "Entelechy".'

Driesch conceives of 'Entelechy' as 'an agent at work in nature', 'of a non-spatial nature', without a seat or localization; it is unmaterial, and it is not energy; it is not inconsistent in its agency with the laws of energetics; its function is to suspend and set free, in a regulatory manner, pre-existing potentials, i.e. pre-existing faculties of inorganic interaction.

Argument from Organic Evolution.—It is convenient to speak of 'cosmic evolution', 'inorganic evolution', 'the evolution of the solar system', 'the evolution of the earth', 'the evolution of scenery', and so on; but there is a risk of identifying processes which are really very different.

In biology it is usual to draw a distinction between the two terms—development and evolution. Development (Haeckel's ontogeny) is the becoming of the individual; Evolution (Haeckel's phylogeny) is the becoming of the race. How do these agree and differ? In both there is a succession of stages, and the scientific assumption is that each stage is conditioned by the preceding stages. In development the continuity between successive stages is one of personal identity; it is the same organism from start to finish, though, as we have seen in the chapter on 'The Cycle of Life', there are some apparent contradictions. In racial evolution, however, the stages are physically discontinuous. Although we speak of the continuity

of the germ-plasm, we must admit that one generation is not personally identical with preceding or succeeding generations.

But the radical difference is surely this, that in any stage in racial evolution there are numerous individuals that do not figure in the final result; they are outside the pale of success; they die before their time or they have small families; in any case they and theirs are eliminated in Nature's sifting. They do not count. They are 'cast as nothing to the void'. It is easy enough to find in some individual life-histories, complicated by metamorphosis and the like, instances of the suppression or elimination of parts, but there is nothing in development comparable to the staking of individual lives and losing of them that has gone on throughout the whole of that sublime and romantic adventure which we call organic evolution.

It seems to us therefore that it would be more accurate to speak of the *development* of the earth, the *development* of the solar system, and so on, keeping the term *evolution* for the organic and the super-organic. Better still would it be to find another term for the sequence of changes in an inorganic system; and some distinguished men of science have recognized this in speaking of 'the story of the heavens', 'the story of the earth', and so forth.

This question of words matters a good deal. As Hobbes finely said, words are only intellectual counters with which the wise do reckon, but they are the money of fools; yet words make fools of us all. The fundamentally important thing is to avoid verbally identifying processes which are really very different. In the succession of inorganic changes, there are no alternatives; every stage is the necessary outcome of its antecedents; all is mechanically

determined; the chains are of iron. In the succession of organic changes there are alternatives, as a species may show in splitting into two or more equally successful species; the creatures are genuine agents in a fashion quite different from that of streams of water or ice which diverge and combine; in short, the mechanical categories are transcended. We are not unaware of the analogies between the inorganic sequence of changes and the evolution of organisms that have often been indicated, and that Herbert Spencer made much of; they are fascinating but unconvincing. It is said, for instance, that 'the process by which worlds emerge from the primal nebula depends upon the conflict of attractive and repulsive forces', just as the process by which species emerge from a primal stock depends upon the struggle for existence. But 'the conflict of attractive and repulsive forces' is a phrase which must be used in a large and metaphorical sense—which is what Darwin said in reference to the phrase 'struggle for existence'.

What we have in the realm of organisms is a continual creation and experimenting on the one hand, and a continual sifting on the other, but the sifting is often a very gentle process. At the best, in comparing inorganic and organic 'evolution', we do not get beyond formal resemblances.

The reasons why many biologists cannot accept as adequate any mechanical description of organic evolution centre in the nature of the organism. The organism plays such an active part. It is active in its variations, which are experiments in self-expression, though some environmental stimulus may pull the trigger which liberates them. It is in some measure active even in the process of natural

selection, for it does not simply submit to the apparently inevitable. It often evades its fate by a change of policy or of environment; it compromises, it experiments; it is full of device and endeavour. It is certainly much more than a pawn in the hands of Fate or Environment; it plays its own game. Besides the variability or inventiveness, which, from the germ-cells outwards, offers solutions to life's problems, there is the organism's utilisation of these assets, and there is the equally fundamental entailment or hereditary registration of the successful new departures without which evolution were impossible.

The Continuity of Evolution.—Immense gaps in our knowledge are immediately apparent when we inquire into the origin of living organisms upon the earth, the beginnings of intelligent behaviour, the origin of Vertebrates, the emergence of Man, and so on. We know very little as yet in regard to the way in which any of the 'big lifts' in evolution have come about, and yet we believe in the continuity of the process. That is implied in our ideal concept of evolution, which we accept as a working hypothesis. It is not very easy to say what it is that is continuous, but we mean in part that there is at no stage any intrusion of extraneous factors. But this continues to raise in the minds of many the difficulty that the results seem much too large for their antecedents. Can we believe that the world of life, with its climax in Man, has been evolved from a nebulous mass?

Let us recall Huxley's famous statement of his radical mechanism :—

'If the fundamental proposition of evolution is true, namely, that the entire world, animate and inanimate, is the result of the mutual interaction, according to definite

laws, of forces possessed by the primitive nebulosity of the universe, then it is no less certain that the present actual world reposed potentially in the cosmic vapour, and that an intelligence, if great enough, could, from his knowledge of the properties of the molecules of that vapour, have predicted the state of the fauna in Great Britain in 1888 with as much certitude as we say what will happen to the vapour of our breath on a cold day in winter'.

This strong and confident statement includes several assumptions regarding which one may fairly argue. Thus Professor Bergson calls attention to its practical denial that time really counts. 'In such a doctrine, time is still spoken of; one pronounces the word, but one does not think of the thing. For time is here deprived of efficacy, and if it *does* nothing, it *is* nothing'. Huxley practically denies the creative individuality of organisms which trade with time in a spontaneous and unpredictable way all their own.

The 'fundamental proposition of evolution' (which Huxley invoked) is of Man's own making, and we are not inclined to be coerced by it into believing that the state of the British fauna either in 1888 or in 1914 could have been predicted by any intelligence however great from a 'knowledge of the properties of the molecules' of the cosmic vapour. Not only because we believe that time counts with living creatures, but because molecules and the like are concepts of physical science used for the description of certain abstracted aspects of reality—used to describe things for a particular purpose or from a certain point of view. It is true that they correspond to that aspect of reality so accurately that we risk lives and fortunes on them, but to say that they exhaust the reality

appears to us not only an unwarrantable assumption, but a contradiction in terms.

The 'primitive nebulosity of the universe', or of our solar system at any rate, has probably its analogues in the heavens of to-day, where worlds can be seen a-making. As far as its movements and condensations and such like went, it might have been physically described, and it could not have been described in any other way. But if within that whirling sea of molecules there 'reposed potentially the present actual world', then the physical description would not have been the whole truth about it. Yet we do not know how the physicist could have indicated that his description was not exhaustive. Whenever we think of facts like intelligent behaviour among animals or the reasoned discourse of Man, who has harnessed electricity to his chariot, has made the ether carry his messages, has annihilated distance, has coined wealth out of the thin air, and has begun to control heredity itself, we feel that if these qualities reposed potentially in the nebula's whirling sea, the physical description which might have been given could not have been exhaustive. Rather would we fall back on the fundamental proposition of evolution which Aristotle discerned, That there is nothing in the End, which was not also, in its quality, in the Beginning. Our philosophical position is briefly, That in the Beginning was the Logos.

Bergson's View.—The two modern thinkers who have most appreciated the wonder of life—that is to say, the relation of theory of life and theory of knowledge—are Professors Henri Bergson and Hans Driesch. We have already referred, in a necessarily inadequate way, to Driesch's rehabilitation of the Aristotelian conception of

Entelechy; we venture to refer—it must be very inadequately again—to Bergson's conception of the origin and nature of life. Bergson's metaphysical theory is that a broad current of consciousness penetrated matter, carrying matter along to organization. He does not keep us in doubt as to what he means by life. Life is consciousness launched into matter—'availing itself of a slight elasticity in matter', 'using matter for its own purposes'. Consciousness, or rather supra-consciousness, is at the origin of life, and consciousness appears as the motive power in evolution. 'Consciousness, or supra-consciousness, is the name for the rocket whose extinguished fragments fall back as matter; consciousness, again, is the name for that which subsists of the rocket itself, passing through the fragments and lighting them up into organisms. But this consciousness, which is a *need of creation*, is made manifest to itself only where creation is possible. It lies dormant when life is condemned to automatism; it wakens as soon as the possibility of choice is restored'. In fact an organism is conscious in proportion to its power to move freely—a quaint metaphysical apology for athletics. In the course of evolution it becomes more and more free as the sensori-motor system becomes more perfect. 'But, everywhere except in man, consciousness has let itself be caught in the net whose meshes it tried to pass through: it has remained the captive of the mechanisms it has set up'. With man, however, a new freedom began. Consciousness is breaking its chains. How free it may become, who shall say?

A Suggestion.—Under the sway of his evolution-idea, the biologist finds it difficult to entertain the hypothesis of consciousness being launched into matter as a bolt from

the blue. May it not have been that the *anima animans* has been with creation through and through, and from first to last? We think of the majestic order of the heavens and the perfection of the dew-drop, of the extraordinary surge of our whole solar system towards some unknown goal, and of the internal 'life' of crystals. We wonder

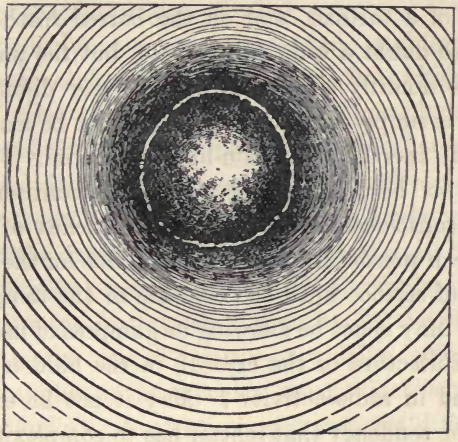

FIG. 100.—Rings formed by placing a drop of 80 per cent. silver nitrate on a thin layer of 5–10 per cent. gelatine, which contains about 0·1 per cent. of potassium bichromate. The gelatine under the drop is coloured red-brown, silver chromate being precipitated. Outside that a dull, white margin is formed which spreads slowly outwards. As the diffusion goes on the rings of similar precipitation of silver chromate are formed at a little distance beyond the area of uniform precipitation. (*After* Liesegang.)

if Time has, after all, simply flowed over the opal and the agate, and whether the beryl has garnered no fruits of experience. A photograph of a zoophyte—e.g. *Sertularia cupressina*—is extraordinarily like the beautiful dendritic frescoes which imprisoned Manganese makes on the wall of its cell! To take another example, we admire the intricate zonal structure of Liesegang's rings—formed, for instance,

when a big drop of silver nitrate is placed on a film of gelatine in which there is a trace of potassium bichromate. There we see, as the diffusion and precipitation proceed, the rings of growth on a salmon's scale and the zones of the otolith in his ear. There we see, as the diffusion and precipitation continue, the zones of growth in the stem of an oak, in the recesses of a pearl, in the vertebra of a fish, on the scale of a tortoise, and on the barred feather of the hawk. No doubt a wide gulf is fixed, but the phenomena are extraordinarily similar as well as very different, and our point is simply that too much must not be made of the quality of 'inertness' in non-living material.

May it not be that an aspect of reality continuous with the clear consciousness in the higher reaches of life has always been present, though it is negligible for the practical purposes of science until the confines of the inorganic are passed? May it not be allowing us glimpses of its presence in the architecture of the crystal, in the hidden 'life' of jewels, and in radio-activity? May it not be expressing itself in the tendency that matter has to complexify—passing from atom to molecule, from simple molecule to complex molecule, and from molecule to colloid masses? May it not lie behind the inorganic evolution which we are beginning to discover? May it not have been resident in the nebula of our solar system, and be contemporaneous with the primeval Order of Nature.

In Conclusion

A consideration of the everyday functions of organisms, of their behaviour, of their development, and of their evolution, leads us away from Kant's view that there is one science of nature, and leads us to follow Driesch and

others in maintaining that Biology must be ranked beside Physics as a fundamental and autonomous science. Another line of argument would, we believe, lead us, even from the naturalist's point of view, to recognize the autonomy of Psychology.

We recognize, then, three orders of facts: the physical order, where mechanism reigns, where mechanical formulæ suffice for the description of what goes on; the animate order, where mechanism is transcended; and the psychical order, where mechanism is irrelevant. It is plain that the physical order overlaps the animate order, for organisms are material systems, and their life includes a concatenation of chemico-physical processes. At the same time, as we have seen, we cannot explain the fundamental properties of the organism, which we start with in biology, in chemico-physical terms, nor would a complete chemico-physical description of what goes on in the life of the organism be the kind of description which a biologist seeks. The same applies to the psychical order, which is overlapped by the biological. In short, the sciences are differentiated not only by their subject matter, but by their characteristic questions and methods and concepts.

Perhaps we may be allowed to refer to three remarks which are often made in regard to this sort of discussion by the plain man in the street, from whom most of us, after all, are not far removed. He is surprised, in the first place, at the longevity of the problem of vitalism and the oscillations of human judgment from one side to another. An old question indeed, for Aristotle was a thorough-going vitalist, and his biology was in conscious opposition to the school of Democritus. And from that time we have had periodic oscillations between vitalistic and mechanistic

interpretations. Now the organism is a machine, and again it is a spirit; now it is a free agent, and again it is only an automaton; now engine and again entelechy.

There are several reasons for this continual see-saw, the chief one being that there is truth on both sides. For the purposes of chemistry and physics the organism may be adequately considered as a material system; for the purposes of biology another aspect of its reality has to be recognized.

But another reason is given by Bergson in his theory of the limitation of our intellect. 'The intellect, so skilful in dealing with the inert, is awkward the moment it touches the living'. 'It is characterized by a natural inability to comprehend life'. 'Created by life, in definite circumstances, to act on definite things, how can it embrace life, of which it is only an emanation or an aspect? Deposited by the evolutionary movement, in the course of its way, how can it be applied to the evolutionary movement itself?' 'In vain we force the living into this or that one of our intellectual moulds. All the moulds crack.'

What then can be done? Some would say, 'Nothing! Let us cultivate our garden'. Bergson's suggestion is, that our method of pure intellectualism is wrong. The line of evolution that ends in human intelligence is not the only one. Other forms of consciousness, such as instinct, 'express something that is immanent and essential in the evolutionary movement. Have we not powers complementary to the understanding by which we may get a vision—a fleeting vision—of what life essentially is'? We have a fringe of instinct.

Some of the tough-minded, or we ourselves in tough-minded moods, are apt to depreciate that 'fringe of vague

intuition that surrounds our distinct—that is, intellectual —representation'. According to Bergson it is an invaluable organon.

In sympathy, in artistic and poetic feeling, we come near instinct. We speak of the intuitive insight of the 'born doctor' and the divining sympathy of the mother. Bergson says that we do well so to speak. 'Instinct is sympathy; if it could extend its object and also reflect upon itself, it would give us the key to vital operations—just as intelligence guides us into matter'. 'By intuition', he says, 'I mean instinct that has become disinterested, self-conscious, capable of reflecting upon its object, and of enlarging it indefinitely'. It brings us sympathetically into life's own domain, and makes us feel sure once more that Wordsworth, Emerson, Meredith, and other nature-poets are truest, because deepest, biologists of us all.

In the second place, the plain man wonders why we should worry over such an academic question as the number of the sciences. Vitalist or mechanist—a plague o' both your houses!—will either view make any difference to this life of mine? This raises large questions, but one answer must suffice. If the mechanistic theory of the organism be erroneous—a false simplicity or materialism—it behoves us in the love of truth to fight, all the more that those who maintain that biology is only applied chemistry and physics are of the company of those who say that psychology is a branch of physiology and sociology a pseudo-science. This position may be held with conviction in the name of scientific method and interpretation by men who are as much impressed as any with the fundamental mysteriousness of nature, but it tends with the careless to strengthen the hands of the unpoetic, the unromantic,

and the wonderless, who darken the eyes of their understanding.

In the third place, the plain man says: 'This big talk about the autonomy of the organism, and so forth, is all very well, but do you mean that there is in the living creature more than meets the eye? Is there more than matter and energy, or not?' The disappointing scientific answer must be that the question is not rightly put. We do not know what matter really is, nor what all the energies of matter may be. What we do know is that present-day physico-chemical formulæ do not suffice for the biological descriptions of organisms, and that we require to use historical explanations which are beyond the limits of physics and chemistry. And we find no warrant for asserting that the physical concepts of 'matter' and 'energy', abstracted off for particular scientific purposes, exhaust the reality of Nature. Very much the reverse.

We see before us an ascending series of individualized activities correlated with an increasing complexity of material organization—the two aspects are inseparable: the worm is a higher synthesis than the mineral, and the bird than the worm, but we cannot explain the fundamental properties of these successive syntheses in terms of anything else. We feel sure, however, that organisms reveal or express a deeper aspect of reality than crystals do (deeper, because it is nearer to what is most real to ourselves, our own conscious experience), and that in this sense there is more in the plant than in the crystal, more in the animal than in the plant, more in the bird than in the worm, and more in man than in them all.

FINIS

Envoi

[*From Huxley's translation of Goethe's Aphorisms.*]

Nature! We are surrounded and embraced by her: powerless to separate ourselves from her, and powerless to penetrate beyond her. . . .

We live in her midst and know her not. She is incessantly speaking to us, but betrays not her secret. . . .

She rejoices in illusion. Whoso destroys it in himself and others, him she punishes with the sternest tyranny. Whoso follows her in faith, him she takes as a child to her bosom.

She wraps man in darkness, and makes him for ever long for light. She creates him dependent upon the earth, dull and heavy; and yet is always shaking him until he attempts to soar above it. . . .

I praise her and all her works.

She has brought me here and will also lead me away. I trust her. She may scold me, but she will not hate her work. It was not I who spoke of her. No! What is false and what is true, she has spoken it all. The fault, the merit, is all hers. . . .

Every one sees her in his own fashion. She hides under a thousand names and phrases, and is always the same.

I praise her and all her works. She is silent and wise. I trust her.

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